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VEGETABLE PHYSIOLOGY

AND

SYSTEMATIC BOTANY.

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BY

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PREFACE.

THE object of the following Treatise is to communicate such a general view of the structure and growth of plants, and of their natural classification, as should be at the same time popular in its form and scientific in its principles. The botanist has too frequently concerned himself, almost or quite exclusively, about the collection of specimens, the examination of their external characters, and the determination of their names; all the wonders and beauties of their internal structure, and the interest derivable from the observation of the uses of their several parts or organs, being very commonly overlooked. It is not among the least of the advantages of the natural system of classification, that, as its divisions are founded upon correspondences and differences in internal conformation, instead of being based upon external characters only, the general adoption of it has necessarily caused much more attention to be paid to the organization of plants; and this has naturally led to increased observation of their functions and habits of life, to the study of the conditions on which their growth and propagation are dependent,

and to the application of the knowledge thus acquired to the improvement of the art of cultivation, whether in the field, the garden, or the hothouse.

The first part of the following volume is, therefore, devoted to an exposition of this part of Botanical science; and the Author has endeavoured to state in the Introduction some of the inducements which may incite to the study of it. He may here remark, in addition, that the progress of science is continually rendering closer and closer that relation between the physiology of plants and that of animals, which it was the Author's intention to develope, in his "Principles of General and Comparative Physiology," first published in 1838. It had long been admitted, that the physiology of man cannot be properly understood, unless studied in connection with that of the lower animals; and the truth, that the physiology of animals cannot be properly understood, unless it be studied in connection with that of plants, is now becoming generally recognized. Those who shall peruse the Treatise on Animal Physiology in this series, after they have made themselves acquainted with the first part of the following volume, will not find it difficult to perceive the connection here referred to.

With regard to the portion of the volume devoted to

Systematic Botany, the author would remark, that the reasons which have induced him to prefer the Natural System to the Linnæan,—the latter having been hitherto almost universally employed in elementary treatises on Botany—will be found fully stated in Chapter XIII. He has not aimed to give an account of every order, since this would have been of very little use to the beginner. In making a selection, he has regarded those as having the best claim to notice, which contain plants of the greatest importance to man, or which present some remarkable peculiarities of structure or habit; a few have been introduced, however, which possess neither of these distinctions, either as containing well-known British plants, or on account of their great abundance in particular spots of the globe. The Cryptogamia have not been treated of in this division of the work, since a general view of their chief groups is contained in Chapter II., and further details would not have possessed sufficient interest for the unscientific reader.

For various reasons, he has thought it best to adopt the system of De Candolle, as being the one most in use at the present time; but he has derived great assistance from the systematic works of Dr. Lindley, and especially from the useful but expensive "Ladies' Botany" of that

author, which he would strongly recommend to such of his readers as can gain access to it. He would remark, in conclusion, that any systematic Treatise like the present must consist, in great part, of materials collected by other naturalists; and that the merit of an elementary work must consist rather in the judgment shown in the selection and arrangement of the materials, than in the originality of its contents. How far he has succeeded in his present attempt, it will be for his readers to decide.

ADVERTISEMENT.

The object of the following Treatise is to communicate a popular, but at the same time a scientific, view of the chief tribes of Flowering Plants, arranged according to the Natural System. The Author is not aware that any similar attempt has been heretofore made, to embody this arrangement in a work of a strictly elementary character, excepting in the useful but expensive "Ladies' Botany" of Dr. Lindley, which he would strongly recommend to such of his readers as can gain access to it. Being persuaded, however, that through the aid of this System alone can any definite idea be gained, of the vast extent and varied aspect of the Vegetable Kingdom, he has not hesitated to employ it here. In his selection of Orders, he has regarded those as having the best claim to notice, which contain plants of greatest importance to Man, or which present some remarkable peculiarities of structure or habit; a few, however, which possess neither of these distinctions, have been introduced, as containing well-known British plants, or on account of their great abundance in particular spots of the globe. The Cryptogamia have not been treated of in this Part, since a popular view of their character was included in the former one; and further details would not have possessed sufficient general interest.

W. B. C.

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INTRODUCTION.

Of all departments of Science, there is perhaps no single one capable of exercising such an advantageous influence on the mind of its cultivator, as Natural History. Every kind of knowledge has in it something that is valuable; for, even if it be of no direct utility in the ordinary concerns of the world, the acquirement of it is a useful exercise to the mental faculties, and the possession of it may operate in a most beneficial manner on the habitual feelings, and give a corresponding direction to the whole course of life.

It is desirable to cherish correct views of the benefits of different kinds of knowledge, that those may choose most advantageously for themselves whom the necessary business of life debars from the extended pursuit of it; and without undervaluing other branches of Science, it may be safely affirmed that Natural History is capable of affording more to interest and instruct, more to refresh and relax the well-disposed mind, on a very slight acquaintance with it, than any other pursuit. Not a step can the learner advance in it, but he meets with wonders previously unsuspected;—not a height does he gain, from which his prospect is clearer and more extensive, but his notion of these wonders acquires a yet more astonishing vastness. The more he knows, the more he desires to know; and the further he advances, the more does he perceive how much delight is yet in store for him.

The beneficent Creator of all has not only ordained, that every part of His works should be *good*—should be adapted to answer its designed end, and should contribute in the highest degree of

which it is capable to the well-being of His creatures;—but He has made every thing "beautiful in its season,"—He has so formed the mind of Man that it derives pleasure from the contemplation of the glorious works around him. And it is, therefore, a worthy employment of our faculties to encourage this pleasure; and to place it upon a more solid and extended foundation, than that afforded by the mere forms and colours of the objects around us, however beautiful these may be.

One great source of the pleasure derived from the inquiry into the structure and mode of existence of the living beings around us, arises from the beautiful adaptation of their parts to each other, and of the whole to the place it has to occupy, which we can easily trace in every one. The Philosopher who studies the motions of the heavenly bodies, and the station of this earth among them, traces these adaptations no less clearly; but it requires profound and long-continued study to be able to comprehend them aright. The Naturalist, however, can discern them with far less research, in every plant that grows, in every animal that breathes; and he meets with a constant variety, which prevents him from growing weary of the pursuit. Yet the young are too frequently kept in ignorance of the wonders and beauties around them; and, whilst encouraged to learn many languages, and read many books, they remain unacquainted with the bright volume of Creation, the pages of which are daily and hourly unrolled before them, "written," to use the impressive words of Lord Bacon, "in the only language which hath gone forth to the ends of the world, unaffected by the confusion of Babel." But these pages are not to be read without some study: the alphabet and grammar must be learned, in order that their beauties may be rightly comprehended; and those who are entering upon the inquiry need to be rightly directed by those who are more advanced.

Natural History has been too generally shunned, as a Science of hard names and intricate classification, by those whose minds

are occupied with the necessary employments and cares of the world, and who seek in the pursuit of knowledge a source of refreshment and relaxation. But the objects of its several departments are not commonly understood. The study includes the examination of the structure, habits, and mode of existence of all the living beings which so thickly people the surface of the globe; and it is only in order to become acquainted with these more readily, that the Naturalist arranges or classifies them, placing those together which have most in common, and separating these from others which are widely different. Classification, therefore, is not the object of Natural History, but a means of gaining that object; and it is very easy to enter upon many interesting inquiries, without the slightest knowledge of it. The structure and actions of Man, for example, may be examined in the greatest detail, without knowing anything of his place in the general scale of being (although such knowledge will often shorten the student's labour); and other kinds of animals and plants may be observed in the same manner. In fact, several of the most valuable and interesting observations we possess, upon the habits and actions of particular animals, were made by hose who devoted themselves almost exclusively to that special object. Thus it is scarcely out of the power of any one to contribute something to the general stock of knowledge; still less, then, can any be prevented from adopting some department of this pursuit, for the health and invigoration of their own minds.

The study of the structure and actions of Plants, constituting what is known as Vegetable Physiology, has been less brought under the notice of those who pursue Natural History only for the improvement and recreation of their minds, than it perhpas deserves. In regard to the importance of the Vegetable Kingdom in the economy of Nature, it can scarcely be said to rank lower than the Animal Creation; for all Animals are either directly or indirectly dependent upon Vegetables for their sustenance, and must cease to exist if they were destroyed. The

beauty of the external forms of Plants is surpassed by that of their internal structure; and the investigation of the latter is more easy than that of animals, besides being unattended with many drawbacks which must elsewhere be encountered. The objects of the Physiologist are never out of reach; for barren indeed must be that country, which affords no shelter to the products of the Vegetable Kingdom. The meanest and most common herbs are, in his eyes, as interesting as the majestic tree or the rarest flower. The toilsome labours of the Collector, who seeks to bring together in his cabinet as large a number as possible of the different tribes of plants existing on the surface of the globe, are not required by him; nor is his mind fatigued by the difficulties and technicalities of classification. And what renders the pursuit of this branch of Natural History peculiarly adapted to the female sex, is its freedom from the necessity of that corporeal suffering, which, however laudable its ultimate objects, the truly humane will always dread to inflict upon beings that have feelings like their own.

The object of the following Treatise will be, therefore, to lead those who may be disposed to adopt our recommendation, to a pursuit which cannot fail to prove a source of interest and improvement. It will be adapted as much as possible to such as have no previous information on the subject, beyond that which all young persons of ordinary capacity may gain by themselves; and it will omit, therefore, several topics of high but less general interest, which those who feel inclined to examine them will find fully treated elsewhere.

Wherever circumstances are compatible with Vegetable existence, there we find plants arise. It is not only on the luxuriant soil, on which many generations have flourished and decayed, that we find the display of their beauties. The coral island, but recently elevated above the level of the sea, speedily becomes clothed with verdure. From the materials of the most sterile

rock, and even from the yet recent cinders and lava of the volcano, Nature prepares the way for vegetable existence. The slightest crevice or inequality is sufficient to arrest the invisible germs that are always floating in the air; and the humble plants which spring from these soon overspread the surface, deriving their chief nutriment from the atmosphere. Having completed their allotted period of existence, they die and decay; but *their* death is only a preparation for the appearance of higher forms of vegetable structure. They are followed by successive tribes of plants, of gradually increasing size and strength; until, in the course of years, the sterile rock is converted into a natural and luxuriant garden, of which the productions, rising from grasses to shrubs and trees, present all the varieties of the fertile meadow, the tangled thicket, and the widely-spreading forest.

No extremes of heat or cold seem to put an entire check upon vegetation. Even in the desert plains of the torrid zone, the eye of the traveller is often refreshed by the appearance of a few hardy plants, which find sufficient materials for their growth in these arid regions. And wherever a spring of water moistens the soil and atmosphere around, a spot of luxuriant verdure is found. These Oases, as they are termed, are the stations at which caravans halt, when crossing the extensive wastes of parching sand; and although their effect upon the mind is doubtless heightened by the dreariness of the preceding journey, there is no question that few spots can present greater richness of vegetation than these. It will be seen, hereafter, that heat, light, and moisture form the circumstances most favourable to the growth of plants; and it is from the combination of the latter of these conditions with the former, that the vegetation of small islands in the tropical ocean is so peculiarly rich. These Oases are like such islands in the midst of a sea of sand; and nothing can be a greater contrast with the desolation around, than "the green pastures" and "still waters" which they afford.

Many remarkable facts might be mentioned, relative to the

degree of heat which some forms of vegetation are capable of sustaining, and which, to some species, indeed, appears a natural and even necessary condition. A hot spring in the Manilla islands, which raises the thermometer to 187°, has plants flourishing in it and on its borders. In hot springs near a river of Louisiana, of the temperature of from 122° to 145°, have been seen growing not merely the lower and simpler plants, but shrubs and trees. In one of the Geysers of Iceland, which was hot enough to boil an egg in four minutes, a species of *Chara* has been found growing and reproducing itself; and vegetation of an humble kind has been observed in the similar boiling springs of Arabia and the Cape of Good Hope. One of the most remarkable facts on record, in reference to the power of vegetation to proceed under a high temperature, is related by Sir G. Staunton, in his account of Lord Macartney's embassy to China. At the island of Amsterdam a spring was found, the mud of which, far hotter than boiling water, gave birth to a species of Liverwort (§. 32). A large Squill bulb, which it was wished to dry and preserve, has been known to push up its stalk and leaves, when buried in sand kept up to a temperature much exceeding that of boiling water.

Even the extreme of cold is not fatal to every form of vegetable life. In the realms of perpetual frost, the snow which covers mountains and valleys, and whose surface scarcely yields to the influence of the solar rays at midsummer, is in some places reddened for miles together by a minute vegetable, which grows in its substance, and has been supposed, from its very rapid increase, to have fallen from the sky. This will be hereafter described under the name of Red Snow (§. 48), which is that commonly applied to it. The Lichen which forms the winter food of the Rein-Deer (§. 39), grows entirely buried beneath the snow; and its quantity may be judged of, by the number of the animals which find in it their sole support, during a considerable part of the year.

Plants are found, too, in situations in which some peculiar noxious influence might be supposed entirely to prevent their growth;—as for example, in sulphureous springs. In fact, there are scarcely any circumstances, in which there is not some kind of plant adapted to exist. Thus, it is well known that soils, which have any considerable admixture of metallic ores, are not favourable to most kinds of vegetation; and among such soils, those mixed with the refuse of lead-mines are the most sterile, so that this substance is often mixed with gravel, to prevent weeds from growing on garden-walks. Yet even on heaps of this material, thrown up around the openings of the mines, the Vernal Sandwort thrives, growing perhaps even more luxuriantly than in any other situation.

The degree in which vitality is sometimes retained by Plants, under conditions apparently the most unfavourable, for a period to which it is difficult to assign a limit, is one of the most interesting and curious circumstances in their economy. In the greater part of those inhabiting temperate climates, an apparently complete cessation of activity takes place every year. The leaves wither and drop off; the stem and branches are reduced to a state of death-like bareness; and all the changes in which life consists, appear to have entirely ceased. In some instances, the stems also die and decay, the roots only retaining their vitality; yet from these, with the return of the genial warmth and light of spring, a new stem shoots up, and new leaves and flowers are produced,—in their turn to wither and decay. The torpor is not, however, so complete as it appears, in those durable and woody stems which defy the winter's blast; for late experiments have shown that a slight movement of sap takes place even in a frosty atmosphere. In evergreen plants, on the other hand, this cessation of activity is less marked; but the difference between their summer and winter condition is much greater than is apparent. In all these cases, however, the changes are periodical; and are not altogether dependent on external conditions. For

nothing will prevent a plant from shedding its leaves nearly at its usual time; and although by artificial heat, or by removal to a warmer climate, a new crop can be brought out within a short interval, this exhausts its powers, so that few kinds can survive the change of circumstances for any long period. Moreover, the period of inactivity cannot in these cases be prolonged beyond a certain fixed time; for a plant, whose growth in spring is checked by the protracted influence of cold, loses its vitality altogether. But there are some instances in which this condition may be greatly prolonged. Bulbs, for example, of the onion, hyacinth, tulip, &c. have been kept for many years in this dormant state, capable of renewing the active processes of vegetation,—of shooting up leaves and flower-stems into the air, and of transmitting their roots into the soil—for many years; and there does not seem any particular limit to this power. Instances have been related of the growth of bulbs unrolled from among the bandages of Egyptian mummies; but there is reason to believe that deception has been practised on this point upon the too-ready credulity of travellers,—still there is nothing impossible in the asserted fact. Light, warmth, and moisture are the causes of the growth of these curious structures; and when removed from the influence of these, there is no reason why a bulb should not remain unchanged for 100 years, if it can for 10; and for 1000, if for 100. We shall hereafter see that the vitality of seeds under similar circumstances appears quite unlimited. (Chap. XII.)

But there are some plants which, even whilst in a state of active vegetation, are capable of being reduced to a similar torpid condition, and of remaining in it for almost any length of time, without injury to life. There is a kind of Club-Moss inhabiting Peru, which is liable to be entirely dried up, when deprived of water for some time. It then folds in its leaves and contracts its roots, so as to form a ball, which, apparently quite devoid of animation, is driven about hither and thither by the wind; as

soon, however, as it reaches a moist situation, it sends down its roots into the soil, and unfolds to the atmosphere its leaves, which, from a dingy brown, speedily change to the bright green of active vegetation. The Rose of Jericho is the subject of similar transformations; and the common Mosses exhibit the same in a less degree.

These conditions are not the only ones admitting of great variation, and yet most important to the active operations of the vegetable structure. Light is as important as warmth and moisture to the processes of the economy; and yet we find plants adapted to thrive under the almost total deprivation of it. Sea-weeds possessing a bright green colour have been drawn up from the depth of more than 100 fathoms, to which the sun's rays do not penetrate in any appreciable proportion. Many of the Mushroom tribe have been found growing in caverns and mines, to which no rays from the sun, either direct or reflected, would seem to have access; and even more perfect plants have been observed to vegetate, and to acquire a green colour (which is in general only produced under the influence of strong light), in such situations. On the other hand, we find some plants adapted only to exist, where they can be daily invigorated by the powerful rays of a tropical sun, with the complete daily change which results from their total absence, during a large part of the twenty-four hours; whilst there are others whose energies, after remaining dormant during the tedious winter of the arctic regions, are aroused into a brief activity by the return of the luminary on whose cheering influence they depend, and whose rays are not withdrawn from them for weeks or even months together. Neither of these tribes could flourish, if transferred to the circumstances of the other; and, opposite as these circumstances are, we observe that the Creator has adapted living beings to inhabit each, with equal suitableness.

This adaptation of each species to particular circumstances, is often seen in an interesting manner on a small scale, on the ex-

terior of large trunks of trees, old towers, &c. which are thickly clothed with Mosses and Lichens. Many of these avoid the light; and their presence indicates the *north* side of the body to which they are attached. To others, again, the light in all its strength is genial; and they frequent the southern aspect; whilst other forms, intermediate in habits, frequent the eastern and western sides; so that, on going round such a tower or large trunk, we observe a succession of different species which may be compared to that which is presented in the various latitudes, passing from the equator towards the pole. A similar succession, on a larger scale, is seen on ascending a high mountain between the tropics, such as the Peak of Teneriffe. The lower portion exhibits the vegetation of the surrounding country, in all the luxuriance and richness of an island in the torrid zone. Higher up, the traveller meets with productions similar to those found on the borders of temperate regions; and to these succeed those of the medium temperate zone. Above these are perceived the alpine plants, which in northern Europe are found at a comparatively trifling elevation; and to these succeeds the dreariness of perpetual snow. These five distinct zones are well marked on the Peak of Teneriffe; each having a certain set of plants peculiar to it, as the plants of Northern and Southern Europe, and of Northern and Central Africa, are to those regions respectively.

Thus we see that on no part of the earth's surface, under no peculiarities of soil or climate, is vegetation of some kind or other impossible. Every distinct tribe of Plants flourishes naturally under peculiar conditions,—some preferring a warm atmosphere, others a cool one;—some only luxuriating in moisture, and others in the opposite condition of dryness;—some requiring the most intense light, and others only growing in darkness. There are some plants which are very deficient in the power of adapting themselves to slight changes in these conditions; and these are accordingly restricted to certain localities favourable to

their growth, and are hence considered *rare* plants. Thus, for example, there are certain species which require that the air surrounding them should contain a minute quantity of salt, dissolved in its moisture;—these only abound, therefore, near the sea-shore; but they are seen to spring up in the neighbourhood of salt-works, or on lias soils which contain a good deal of saline matter, even many hundred miles inland,—their seeds being conveyed by the wind or by birds, which have spread them over the whole surface of the earth, but *there only* meeting with the conditions they require for their development. On the other hand, there are many which can grow in almost any situation, and which can adapt themselves to a great variety of circumstances, often exhibiting evident changes of form and aspect, which are due to the influence of these. Such are *common* plants; and many of them are among those most serviceable to man, on account of the improvement which can be effected in them by cultivation. For example, the Potato, growing in its native climate—the tropical portion of South America—does not require for the growth of its young shoots that store of nourishment which, in temperate climates, is provided in its fleshy tubers; and the edible portion is thus extremely small, since the warmth and moisture constantly supplied to it develop the growing parts without such assistance. But when transplanted to colder regions, and to a richer soil, that store is greatly increased in amount, and becomes one of the most important of all articles of food to man. If it were not for this capability of adapting itself to new circumstances, the plant could not thrive in Northern Europe; since its own powers of growth would be insufficient, when the external conditions are so much changed. But it is this very capability which renders it so useful to man. If the large Potatoes of European cultivation be planted again in tropical climates, the produce is little superior to that of the original stock; since, when circumstances no longer demand it, the acquired habit ceases. The Cabbage,

Broccoli, Cauliflower, &c., are, in like manner, only *varieties* of one species, greatly altered by cultivation; the plant which was the original stock of all, having been formed susceptible of more remarkable changes than most others, and thus rendered at the same time useful to man, and very easy of production.

These instances, to which many more will be hereafter added, will suffice to show that it is not only in their original state, that the adaptation of each tribe of Plants to particular circumstances is exhibited; since there are many which can thus spread themselves, or may be spread by Man, over a large part of the globe. And in this capability, no less than in their original aspect, do we recognise the wisdom and power of the Almighty Designer, who willed that no portion of the globe should be unclothed by vegetation, and that from every part the herbage should spring forth for the supply of the Animal creation, which is entirely dependent on it, either directly or indirectly, for its sustenance.

Such, then, being the universal diffusion of these beings, it is obvious that in no spot can he who seeks to make himself acquainted with their structure and habits, be without some subjects for examination. And since the humblest and simplest Plants are found, when examined, to display an organisation as remarkably and beautifully adapted to the functions they are to perform, and to the conditions in which they are to exist, as is that of the highest and most complicated, there is no reason why any should be neglected, however insignificant they may appear.

The following Volume is intended to serve as a guide to those who are inclined to make the wonders of the Vegetable Kingdom an object of their regard, either as a source of recreation, or with those higher views to which the student of Natural History can scarcely avoid being led. For although no doubt can be entertained by the reflecting mind, that the Power, Wisdom, and Goodness of the Creator are everywhere operating with equal energy, whether in the simple but majestic arrangement of the heavenly bodies, or in those changes by which our own globe is

rendered fit for the habitation of such innumerable multitudes of living beings, no one can help feeling that it is in the structure and actions of these beings themselves, that these attributes are more evidently manifested to the intelligent observer. And although the Animal kingdom has usually been regarded as affording more remarkable instances of their display than the Vegetable world, it may be doubted whether, when the latter is more closely examined, it will not appear equally or yet more wonderful;—the simplicity of the *means* being most strikingly contrasted with the vastness of the *ends* attained.

CHAPTER I.

OF THE GENERAL CHARACTERS OF LIVING BEINGS, AND THE DISTINCTION BETWEEN ANIMALS AND VEGETABLES.

1. When we examine any common Vegetable, we find that it is composed of a number of parts, differing in their form and structure,—such, for example, as the *stem*, *roots*, *leaves*, and *flowers*. Each of these we might again subdivide into others;—the leaves, for example, into the *footstalk* on which they are supported, and the expanded portion or *blade*. The blade of the leaf may be again distinguished into the *midrib* with the branching *veins* proceeding from it (which form as it were its skeleton), and the soft fleshy portion which clothes these; and we might further convince ourselves, by a little examination, of the presence of a kind of skin or *cuticle*, which envelops the whole. Now these several parts of the structure of a plant, which have their respective uses in maintaining its life,—the roots, for example, being to suck up moisture from the soil through which they spread themselves, and to fix the whole structure in the ground,—the stem to convey this to the leaves, which it elevates into the air, and exposes to light and warmth,—the leaves to convert or elaborate this crude fluid into nutritious sap,—and the flowers to produce seed by which the being propagates its race,—these several parts are termed the *organs* of which the plant is composed; and the uses of these parts—the changes they perform—are called their *functions*.

2. Now it is in the presence of these different organs, that one of the chief distinctions exists, between those structures which possess or have ever possessed life, and dead inert matter. In the stone or the mass of metal, we perceive that every part is similar to

every other part; it has the same structure, the same properties. If it possesses the crystalline form, it may be reduced into an almost indefinite number of smaller crystals similar to itself; and as to its properties, the chemist cares not (except as a matter of convenience) whether he examines a single grain or a mass of a ton weight. Nay, of many substances the properties are so peculiar, that they can be recognised with certainty in quantities so minute as to be scarcely visible; thus, arsenic, when administered as a poison, has been detected after death in a quantity probably less than the hundredth of a grain; and yet the experienced chemist has no hesitation in asserting that this minute crystalline metallic substance *is* arsenic, because he recognises in it the same form and the same properties, which a larger mass of that substance would exhibit.

3. Far different is it with regard to a Plant or Animal. These also may be divided and subdivided; but they then entirely lose their original character; for the parts or organs no longer bear any resemblance to the whole or to each other, either in form, structure, or properties. Thus, then, we see that the bodies which are formed to exhibit those actions to which we give the general term of Life, are peculiarly distinguished from dead matter, by the presence in them of a number of parts or *organs*, distinct alike in their form, structure, and properties; hence such are called *organised* bodies. On the other hand, dead inert matter may be divided, with any degree of minuteness, into parts similar to each other in form, structure, and properties; hence it is termed *inorganic*, or destitute of organs.

4. There is another peculiarity possessed by living beings, in regard to their actions or *functions*. Some of these actions are governed by the same laws as those which operate on inorganic matter; the blood is propelled by the heart of an animal, for example, through its system of branching vessels, just upon the same principle that a forcing-pump drives water through the pipes which convey it over a large city. But the nature of the force is quite different. In the latter case it is merely mechanical. In the former it results from a property peculiar to organised structure, and especially manifested in that form of it

which is called *muscle*;—the property, namely, of contracting, when a stimulus or irritation is applied to it. This and many other properties, therefore, which are exhibited by organised structures, and to which we see nothing analogous in inorganic matter, are termed *vital*; and it is by the operation of these properties, that the series of changes is produced, which constitutes the Life of any organised being, whether Plant or Animal. Thus the heart has the property of contractility, which, when exercised, causes its contraction;—the eye has the property of receiving the impressions of light, which, when exercised, causes sensation;—and so on.

5. It may be asked,—whence do these peculiar properties arise? Are living bodies composed of different *elements* from those which exist around us in the form of dead matter? Or are the elements the same, in a different state of combination? And can we attribute the peculiar properties of organised tissues to the peculiar state in which their particles exist?

6. To this it may be replied, that there is no element entering into the composition of organised bodies, which is not also found in the world around; and further, that their chief elements are very few in number, compared with those which we find elsewhere. But the state of combination in which they exist is altogether peculiar, and such as the chemist cannot imitate; any more than the mechanic can imitate the arrangement of their particles. In fact, every organised structure with which we are acquainted, had its origin in another, which produced a germ capable of living and growing, and of constructing its peculiar fabric out of the materials it derives from the inorganic world; and this again was produced by a former one;—and so on.

7. We perceive, therefore, that—as the living organised beings which we now witness around us, are all the descendants of others, whose succession we might trace backwards to their first parentage,—their actions are as much the results of the general laws which the Creator of all impressed on the frame of His first-formed creatures, as are the movements of the planets round the sun, of the laws which He impressed on them, when He first set those glorious spheres in motion. These laws are

continually maintained by His superintending agency, without which all would be anarchy and confusion.

8. It would seem to be a part of the exercise of those laws, that living beings should take from the inorganic world the materials of their structure,—should convert these into parts of their own fabric,—should endow these with properties similar to those which their previous structures possessed,—and should even produce from them the germs of new structures, capable of performing the same changes. Thus, the germ contained in the seed builds up the beautiful form and wondrous structure of the perfect tree, with scarce any other materials than water and air; and of these it not only constructs its own stem, leaves, roots, and flowers, but (what seems yet more extraordinary) it imparts to its seeds, which, when separated from it and dried up, seem as it were dead, the power of repeating for themselves the same operations. When once we understand it, however, as a general law, that it is a property of organised structures to produce the same, there is little difficulty in comprehending how they impart to the elements they employ, properties so different from those which they previously possessed. For we find in every case, that a change of combination in these elements is attended with a change in their properties. Thus an *acid* (such as oil of vitriol) and an *alkali* (such as soda) have properties peculiar to themselves, and in many respects contrary to those of each other; but when they are brought together, they unite into a new compound, which possesses a form and properties differing from those of either of its elements. Again, sulphur, nitre, and charcoal, when simply *mixed* together in certain proportions, form a product, gunpowder, which possesses properties very different from those of either of its elements. Thus, then, we see that there is nothing improbable in the supposition, which all analogy supports, that the properties peculiar to organised structures depend upon the peculiarity of their constitution; and this peculiarity, which the chemist and the mechanic alike fail to imitate, results, as we have seen, from the general law,—that organised structures can only take their origin from beings already possessed of life.

9. One more preliminary consideration must be adverted to,

before we quit these general views. The properties of organised bodies require certain conditions for their operation. Thus, a seed, which possesses vital properties in a dormant or inactive condition, and which may retain these for hundreds or even thousands of years, if placed in favourable circumstances so to do, begins to germinate or grow, as soon as it is submitted to the proper degree of warmth, moisture, and air. These, then, are the conditions requisite for those changes which we call its Life; for the dry inactive seed can scarcely be said to be *alive;* though, on the other hand, it certainly is not *dead*, since it possesses those properties or capabilities which enable it to live when placed in favourable circumstances. Again, suppose a Plant to be actively vegetating under the influence of light, warmth, and moisture, and to be suddenly deprived of all these,—by being carried, for example, into a cold dark cellar;—all its vital processes receive a check, and it either dies, or, if sufficiently hardy to sustain the shock, it remains inactive until the necessary conditions of its growth be renewed. These conditions are technically called the *stimuli* to vital actions; and thus we see that Life is the result of the operation of these stimuli upon organised structures possessed of peculiar properties. In attempting, therefore, to understand the history of Vegetation, we have three things to consider; in the first place, the nature of the *structure* of plants; next, the *properties* which their several kinds of structure respectively possess; and lastly, the operation of various *external stimuli* upon these properties, so as to produce vital actions.

10. In considering the history of Animal Life, exactly the same course will be gone through; but there will then be an additional subject to be treated of; namely the *internal* stimuli, arising from the *will* of the being, which cause those actions that are termed *spontaneous*, since they have no direct dependence upon external stimuli, but originate in the animal itself. In the history of Man, these actions evidently form a large part; but in the lowest animals they are very obscure, and can often scarcely be distinguished from the actions of plants. But even in man we have no difficulty in recognising a great number of actions

analogous to those which constitute the whole life of plants. Thus the absorption of food, its conversion into a nutritious fluid, the circulation of this through the system, its purification by exposure to the air, and the formation from it of new structures or the reparation of the old,—are all actions over which the mind and will have no direct control, which go on quite independently of it, and which may be regarded as perfectly analogous to the same functions in plants. Hence they receive the name of functions of *vegetative* or *organic* life; whilst those of sensibility and power of spontaneous movement are termed functions of *animal* life, as being peculiar to that division of organised Nature. In fact it is by their presence or absence, that the Animal or Vegetable character of a being must really be determined. For though the external peculiarities of the higher kinds of Plants and Animals are quite sufficient to distinguish them from each other, yet there are many forms of the latter so low and simple, and so destitute of all that is regarded as peculiar to the Animal, that they cannot be readily distinguished from Plants.

11. It is in these lowest forms of both kingdoms, that we recognise the nearest approach to inorganic matter. For we gradually lose, in descending the scale, nearly all appearance of distinct organs; so that the simplest plants—that, for example, which constitutes the Red Snow of Alpine and Arctic Regions (§. 48)—instead of having stems, roots, leaves, and flowers, present us with apparently but a single organ, namely, a globular cell or little bag containing fluid. Even here, however, we shall subsequently find that there is a distinction of parts; and that, whilst the *external* surface is destined to imbibe nutriment from the moisture and air around, the *internal* forms the germs by which this simple little being is multiplied to a prodigious extent.

CHAPTER II.

GENERAL VIEW OF THE VEGETABLE KINGDOM.

12. WHEN we examine, however cursorily, the nature of the Plants around us, we at once perceive that their growth and succession are regulated by certain *laws*. Thus we observe that all have a period of life to which they are more or less closely limited. Many of our commonest cultivated vegetables,—the Corn, the Beans, the Turnips of our fields, and many of the plants which enrich our gardens with their flowers,—live but for a single summer; springing up from seed, uprearing a lofty stem, putting forth expanded and luxuriant foliage, unfolding gay and numerous blossoms, and finally withering away and undergoing complete decay, in the course of a few months. In others, on the contrary, the duration of life is so great that it *seems* to be unlimited; but there is good reason to believe, that the forest trees, which lift their massive stems to the light of day through a succession of many hundred years, have an appointed limit to their lives as regular as that of man,—varying, like his, in individual cases, according to the circumstances of each. Every plant, then, has a period allotted by the great Creator of all, for its springing from seed, the unfolding of its leaves, the expansion of its blossoms, and its subsequent death and decay; but while death is the lot of each generation that "cometh up and is withered," the perpetuation of the race is accomplished by another law, which provides for the production by each individual, before its own dissolution, of the germs of new individuals, from which plants may arise, that go through their allotted period of life, and in their turn decay, after producing the germs of a succeeding generation.

13. Now besides these evident laws, another may be detected by a little observation,—that the beings produced from these germs are in every essential respect similar to their parents: and that thus, after many thousands of generations, every plant or tree of the present day, may be regarded with certainty as having had a representative, at the period of the creation of the vegetation which now clothes our globe.

14. The exceptions which may seem to exist in regard to this law are so in appearance only. The seeds of any particular kind of Apple, for instance, will not produce the same kind with any certainty, but are as likely to give origin to trees that shall bear very different and far inferior fruit. The same be said of the cultivated Dahlia, which presents so many beautiful varieties of colour; the seed of a white flower is not much more likely to produce white Dahlias, than one with yellow or purple flowers. But in these and many more such instances, the different kinds are first produced by the influence of cultivation only, and had all originally but one stock; and it is this stock, common to all kinds, which the seed has a tendency to perpetuate, rather than any one of the varieties which have been obtained from it by the art of man; and we never find any tendency to produce a plant of an entirely different kind. Thus, the sour Crab is the stock of all the rich and delicate varieties of the Apple; and if the seeds of any of these be sown in a poor soil, the plant will bear fruit resembling that of the original; but still it will be an Apple, and never a Pear or a Quince, or any other of the kinds most nearly allied. In the same manner, the original stock of the Dahlia is a plant having a very ordinary yellow flower, with but one circle of coloured florets; but by the influence of cultivation the number of these circles is much increased, and the colours are deepened and enriched, as well as almost infinitely varied. The seeds of any of these, however, when sown in a poor soil, will produce a plant resembling the *original* parent; and thus it is seen that there is no real exception in such cases to the general law,—that the form of the *species* or distinct kind is propagated without any important alteration through successive generations; so that we may regard all the tribes of plants, really distinct

from one another, as having existed in nearly the same form since their first creation.

15. The Naturalist, then, regards as *distinct species* those races of Plants, the differences between which are evident, and are such as are not likely to have resulted from cultivation or any other external cause, and do not exhibit any tendency to alteration in progress of years. Such, for example, are those between the Apple and Pear among Plants, or the Dog and the Fox among animals. Among all the varieties of the Apple, different as they are from one another, there is none which exhibits any close resemblance to the Pear; and of all the kinds of Pear, there is none which so far loses its distinguishing characters, as to show any great similarity to the Apple. And yet among the varieties of the latter, there are kinds which are more different from each other in size, shape, colour, flavour, &c., than some of these are from the Pear; but while all these show a marked tendency to change under different circumstances of growth, the internal differences between the Apple and Pear never exhibit any such tendency, but remain constant through all the varieties of each. The same may be said of the Dog and the Fox; for, though some varieties or breeds of the former seem to differ from each other more than they do from the Fox, yet these differences are liable to disappear altogether when the animals return to a wild state, all merging in a form most nearly resembling that of the Shepherd's dog; whilst the differences between the Fox, and the breeds of Dog most nearly allied to it, are constantly manifested.

16. On the other hand, the Naturalist regards as *varieties* of the *same species*, those Plants and Animals, in the various specimens of which, however dissimilar they may be, the points of difference exhibit such a tendency to variation, that the one kind passes, as it were, into the other. Thus, the Grayhound and the Bull-Dog would be regarded as springing from originally different stocks, if we did not meet with intermediate forms of the Dog, which blend the peculiar characters of both. And the Primrose, Cowslip, and Polyanthus have been regarded as distinct species, so considerable are their differences in form and

structure; but the botanist is now aware, that many forms exist, which are intermediate between these, and that all may be raised from one stock. The same is the case with many other kinds of Plants.

17. This explanation, will, it is hoped, make the meaning of the term *species* understood; and it is very desirable that clear notions on the subject should be acquired by the student of Natural History at the very commencement of his attention to the pursuit. It is computed that from 70,000 to 80,000 distinct species of Plants have been collected by Botanists from the surface of the globe; and probably at least as many more remain to be discovered. It is obvious that an acquaintance with the structure and characters of such a vast number of different races, will be rendered much easier by classifying or arranging them,—placing those together, which have a greater or less amount of general resemblance; and separating others, according to their amount of difference. It is only in this manner, indeed, that any one, within the compass of a single life, can become master of the whole. In making such an arrangement, those species are first assembled into a group, termed a *genus*, which resemble each other in all the more important particulars, and differ only in minor details. For example, the different kinds of Roses among plants, and the Lion, Tiger, Leopard, and other species of the Cat kind among animals, are considered as belonging to the same genus,—their points of agreement being far more numerous than those of difference. Several genera may, in like manner, be united into a *family;* the various members of which have a common resemblance, though with many subordinate differences. By continuing to pursue the same plan, we form divisions of greater and greater extent; until we are at last brought, by uniting subordinate ones, to the primary divisions, into which the whole kingdom may be at once distributed; each of which divisions contains a large number of very dissimilar groups, united together by some common points of general resemblance.

18. Perhaps an illustration may make this subject better understood. If we were to examine the people of any nation, in which there had been but little intermixture among its different

tribes (as was formerly the case in Scotland in regard to the *clans*), we might find a group of persons resembling each other so strongly in countenance, manners, form of speech, &c., and differing so much from all around them, that we should have little doubt of their belonging to one family; and, going further, we might meet with several such groups, each containing several individuals, and each differing in other characters from the rest. But if we were to bring these families together, we should probably be able to trace more general and less marked resemblances among certain of these, which would lead us to associate them in clans, each of them including many families distinguished by certain points of similarity to one another,—as, for example, a strongly-marked feature or a peculiar dialect,—whilst differing in these same points from those of the remaining clans, and also differing from each other in minor points. Again, among these clans we might find some resembling each other, and differing from the rest, in their complexion or language; and thus forming tribes into which the whole nation might be subdivided. And, lastly, this nation would have certain points of conformity with those inhabiting the same quarter of the globe, whilst yet differing still more strongly from them, than its own tribes do amongst each other: and those inhabiting different quarters shall still more widely differ from each other, in general conformation, complexion, language, habits, &c.; whilst still exhibiting those characters which are peculiar to *Man*, and which separate him from all other animals.

19. The primary division of the Vegetable Kingdom is into Phanerogamia or Flowering-plants, and Cryptogamia or Flowerless-plants. Though these designations are not strictly correct, they serve to indicate sufficiently well the character of the tribes, to which they respectively apply. To the former division belong nearly all cultivated vegetables,—the whole of the forest-trees both of our own and of other countries,—and a very large proportion of the vegetation, that naturally covers the surface of the earth, in temperate and warm climates. Many of the tribes contained in it, however, produce no distinct blossom; but these possess the essential parts of the flower (as will be

hereafter explained), and form that perfect seed, which is characteristic of this division. In all the PHANEROGAMIA, (save in a few exceptions which stand, as it were, on the border of the division, and connect it with that of Cryptogamia, of which they exhibit some of the characters,) we find a certain number of distinct parts,—such as the stem, roots, leaves, and flowers; and the germs by which they propagate their race, come to an advanced state before quitting the parent, and are furnished with a store of nourishment, by which they are afterwards assisted in their growth. The *seed* of these plants has, therefore, a complex structure; and the young plant shoots from it in a certain determinate manner (Chap. XII.).

20. In the CRYPTOGAMIA, on the other hand, the parts concerned in the reproductive process are much less evident, and the germs which they form, are much less matured when they quit the parent structure. In the Mosses, Ferns, Sea-Weeds, &c. no *seeds* are produced: but a number of small particles are liberated, which are termed *spores;* and each of these contains within it several minute germs, which spring from it without any particular regularity, and which are not assisted in their growth by any such store of nutriment, as that provided in the seed. The absence of this is a very important character; for it seems a universal law of Nature, that the higher the grade a living being is ultimately to attain, the longer is the period during which it is assisted, either directly or indirectly, by its parent, during the early stages of its growth. Thus Quadrupeds, which bring forth their young alive, and maintain them afterwards by suckling, are higher than Birds, which produce them, in the first instance, in a state far less mature. And Man, who in his adult age rises far above all other animals, is longer dependent upon his parent during the period of infancy.

21. The embryo of the Flowering-plant, contained in the mature seed, is so far advanced at the time of quitting its parent, that it possesses one or two distinct leafy bodies, termed *cotyledons*, which, when the seed begins to germinate (as it is called), are pushed up to the surface of the ground, and there turn to a green colour, and perform all the functions of true leaves, until these

make their appearance. Now of all trace of cotyledons, the embryo of the Flowerless-plant is entirely destitute; and the whole group is hence spoken of as *Acotyledonous*. On the other hand, of the Flowering-plants, some possess *one*, and others *two* cotyledons; and this difference in the structure of the seed is accompanied by so many other differences in the structure of the stems, the leaves, flowers, &c., that it serves to mark the two principal subdivisions of this portion of the Vegetable Kingdom.

ACOTYLEDONEÆ. CONFERVA. MONOCOTYLEDONEÆ. COCOS. DICOTYLEDONEÆ. SINAPIS.

FIG. 1.

That in which one cotyledon exists is termed *Monocotyledonous;* and that in which there are two, *Dicotyledonous*. The common Bean or Pea will serve as a characteristic illustration of the latter; and the Wheat and other Grass-seeds, of the former.

22. The general aspect of the Flowering-plants is sufficiently well known, to render a more minute account of them here unnecessary; since the object of this preliminary view of the Vegetable Kingdom, is to render the student, who may have been previously entirely ignorant of the subject, prepared to enter with advantage on that detailed description of the mode, in which the several tribes grow and reproduce themselves, which it is the object of the Physiological portion of this Volume to communicate. A fuller sketch of the principal divisions of the Cryptogamia will, however, now be given, as few ordinary observers bestow much attention on them.

23. Of all the CRYPTOGAMIA, the *Ferns* approach most nearly to Flowering Plants. The general aspect of those inhabiting this

and other temperate countries, is well known. They present a small number of leaves,—generally much divided into leaflets, and these again often minutely subdivided,—each arising from the ground by a woody stalk, which is commonly regarded as the stem of the plant. The true stem, however, is buried beneath the ground, or sometimes creeps along its surface; and the branches it sends upwards into the air, are really the leaf-stalks. (Fig. 2). In many Ferns of tropical climates, the true stem rises upright, like that of a tree, and bears at the top a beautiful crown of those peculiarly graceful leaves, for which the Ferns are remarkable. The height of these Tree Ferns, which are most luxuriant in the small islands, where they are furnished

FIG. 2.—POLYPODIUM VULGARE, COMMON POLYPODY, OR WALL FERN.

FIG. 3.—TREE FERN.

with a more regular supply of atmospheric moisture than they can obtain at a greater distance from the sea, is sometimes as

much as 40 or 45 feet; so that we must not judge of the whole race, by the comparatively insignificant specimens, which our own climate produces. These stems do not, however, afford any wood sufficiently solid to be employed in the arts. (Fig. 3.)

24. The organs of reproduction in Ferns, have no evident analogy with the flowering system in higher plants. Nothing like a flower is ever seen in this group; and the fructification is incorporated, as it were, with the leaves,—being generally found, when mature, in brown spots or lines on their under surface or at their edges (Fig. 2); the nature of the organs composing these will be hereafter described (Chap. XII.). In most Ferns, *all* the leaves are concerned in producing the fructification; but in some (of which the *Osmunda regalis*, or Flowering-Fern, as it is commonly but incorrectly termed, is an example) certain leaves are devoted to the production of the fructification, and are termed *fertile:* whilst others only perform the usual functions of leaves, and are called *sterile* leaves, from the absence of reproductive power in them. The term *frond* is generally applied to the leafy portions of the Cryptogamia, as distinguishing them from the true leaves of Flowering Plants, which have only one set of offices to perform. Sometimes the fertile frond of Ferns altogether loses its leafy aspect, its edges being completely rolled in, so as to inclose the fructification; and this separation of the reproductive from the nutritive portion of the system, which makes the distinction in Flowering-plants between the flowers and the leaves, is as complete as any which the Cryptogamia exhibit.

25. One of the most interesting peculiarities of the Ferns, is the spiral mode in which its leaflets and leaves are rolled up, before their first appearance; each leaflet being rolled up towards the rib which supports it,—the ribs again towards the midrib, and the midrib towards the footstalk. The unfolding leaves, in a state closely resembling those represented at the top of Fig. 3, may constantly be seen during spring, in spots where this group abounds; and, when examined, display the most provident and beautiful arrangement of the numerous minute parts, of which the whole leaf consists. Few *common* objects, indeed, are more

interesting than this, which requires neither skill, nor the assistance of instruments, for the detection of its beauties.

26. Although Ferns constitute but a comparatively small part of the present vegetation of this country, they must have been much more abundant in a former period of the earth's history, especially at the time when the beds of coal were being formed; since their remains now constitute by far the largest part of those, which are preserved to us with tolerable perfection in a fossil state. This is partly due, however, to the remarkable power which these plants possess, of resisting the action of water; by which other plants and trees were decomposed,—their remains having contributed to form those immense masses of Coal, which are so important to Man, not only for his personal comfort, but for the arts of life. The Ferns are able to withstand the effects of even a very prolonged immersion in water, with scarcely any change; whilst not only the soft tissue of plants, but the heart-wood of most trees, decays so completely under the same circumstances, as to leave little or no traces of their character. In tropical islands, the Ferns constitute a most important part of the whole vegetation; being equal in number, in the Sandwich Islands, to one-fourth, and in Jamaica to one-ninth, of all the Flowering-plants existing in each of these localities.

27. The next principal group of Cryptogamia, that of *Mosses*, is as interesting from the delicacy and minuteness of all the plants composing it, as other tribes of the Vegetable Kingdom are for the majesty of their forms, or the vast extension of their foliage. These are so generally and easily recognised as such, that a minute description of them is at present unnecessary; but it should be stated that the term *Moss* is commonly applied, not only to the true Mosses, but also to many Lichens. The true Mosses, however, are always to be known, by the green colour they possess, except when dried up; while the Lichens are usually grayish in their aspect. Mosses usually possess a sort of stem, round which the minute leaves are arranged with great beauty and regularity; but neither this stem, nor the leaf-stalks of the leaves, have any truly woody structure; and they more closely resemble the simple tissue of the lowest plants, than the complex fabric

of those already noticed, to which they seem to bear a greater resemblance in external form. Mosses do not, like Ferns, bear their fructification upon the leaves or modifications of them; it is inclosed in a little case or *urn*, which is furnished with a lid, and is borne on a long distinct stalk, so as to be very easily observed when full-grown. The interior of this minute organ usually contains a structure of great beauty, which will be hereafter described in detail; but it is interesting to know, that it was by the contemplation of this, that the heart of Mungo Park, the African traveller, was revived, when the difficulties by which he was surrounded had almost extinguished hope within him. The passage has been often quoted; but, it may be hoped, never without its use; and it does not seem superfluous to introduce it here.

FIG. 4.—HYPNUM CASTRENSIS, OR FEATHER-MOSS.

28. This enterprising traveller, during one of his journeys into the interior of Africa, was cruelly stripped and robbed of all that he possessed, by banditti. "In this forlorn and almost helpless condition," he says, "when the robbers had left me, I sat for some time looking around me with amazement and terror. Whichever way I turned, nothing appeared but danger and difficulty. I found myself in the midst of a vast wilderness, in the depth of the rainy season,—naked and alone,—surrounded by savage animals, and by men still more savage. I was five hundred miles from any European settlement. All these circumstances crowded at once upon my recollection, and I confess that my spirits began to fail me. I considered my fate as certain, and that I had no alternative but to lie down and perish. The influence of religion, however, aided and supported me. I reflected that no human prudence or foresight could possibly have averted my present suf-

ferings. I was indeed a stranger in a strange land, yet I was still under the protecting eye of that Providence, who has condescended to call himself the stranger's friend. At this moment, painful as my reflections were, the extraordinary beauty of a small Moss irresistibly caught my eye; and though the whole plant was not larger than the top of one of my fingers, I could not contemplate the delicate conformation of its roots, leaves, and fruit, without admiration. Can that Being (thought I) who planted, watered, and brought to perfection, in this obscure part of the world, a thing which appears of so small importance, look with unconcern upon the situation and sufferings of creatures formed after his own image? Surely not.—Reflections like these would not allow me to despair. I started up; and disregarding both hunger and fatigue, travelled forwards, assured that relief was at hand,—and I was not disappointed."

29. Mosses are found in all parts of the world, in which the atmosphere is moist; but they are far more abundant in temperate climates, than in any between the tropics. They are among the first vegetables that clothe the soil with verdure, in newly-formed countries; and they are the last that disappear, when the atmosphere ceases to be capable of nourishing vegetation. The first green crust upon the cinders, with which the surface of Ascension Island was covered, consisted of minute Mosses. This tribe forms more than a fourth of the whole vegetation of Melville Island, one of the most northerly spots in which any plants have been observed; and the black and lifeless soil of New South Shetland, one of the islands nearest to the South Pole, is covered with specks of Mosses struggling for existence.

30. Besides their power of resisting extremes of temperature, Mosses exhibit a remarkable tenacity of life, when their growth is checked by the absence of moisture; so that they may often be restored to active life, even when they have been dried for many years. Hence they offer abundant sources of interest to the observer of Nature, at a season when vegetation of other kinds is almost entirely checked. For it is most curious to observe, how gay these little Mosses are on every wall-top, during the winter months, and in the early spring,—almost, or perhaps

the only things, which seem to enjoy the clouds and storms of the season. They choose the most exposed situations, spread out their leaves, and push up their delicate urns, amidst rain, frost, and snow; and yet there is nothing in their simple and tender structure, from which we could infer their capability of resisting influences so generally destructive to vegetation. But it is with Plants as with Animals.—The more simple and lowly the being, the greater is usually its tenacity of life, under circumstances which depress the vital powers of higher kinds; whilst the influences which *they* require are often too powerful for it. Thus, Mosses and Lichens, over-stimulated by heat and dryness, wither away in summer; but vegetate freely at a season when there is no other vegetation, and when their humble fabrics cannot be overshadowed by a ranker growth.

31. Mosses were fancifully termed by Linnæus, *servi*, servants, or workmen; for they seem to labour to produce vegetation in newly-formed countries, where soil can scarcely yet be said to be. This is not their only use, however. They fill up and consolidate bogs, and form rich vegetable mould for the growth of larger plants, which they also protect from cold during the winter. They likewise clothe the sides of lofty hills and mountain-ranges; and powerfully attract and condense the watery vapours floating in the atmosphere, and thus become the living fountains of many streams. They are sometimes so completely dried up by drought, that they escape notice; and then, when moistened by rain, they appear to have suddenly clothed a barren heath, or overspread a dry wall with verdure, on which, however, they really existed before.

32. Closely connected with the Mosses is the tribe of *Hepaticæ*, or *Liverworts*, the lower forms of which are nearly connected with the Lichens. Some of them differ but little in their general characters from

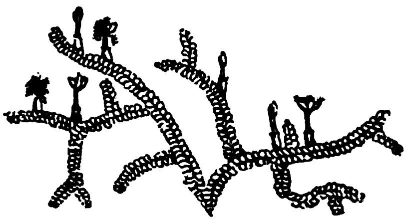

Fig. 5.—Hepaticæ, or Liverworts.

Mosses, being distinguished by certain peculiarities of fructification. Others, however, have no distinct stem or separate leaves; but extend horizontally into a flat leaf-like expansion; the fructification is sometimes elevated above this on a little stalk; but in the tribes most nearly allied to the Lichens, it is imbedded in it, as it is in that group. Their general habits closely resemble those of the Mosses. Their leafy expansions are soft and green; differing much, therefore, from the dry scaly crusts of the Lichens. They are capable of reviving, like the Mosses, after being dried up; and, from the rapidity of their growth, and a peculiarity in their mode of propagation, they are often seen to spread over a damp surface with great rapidity. One of the most common species is the *Marchantia polymorpha*, which will be often referred to in this treatise, on account of the many interesting facts which the attentive study of it has disclosed. It is usually found growing on moist surfaces, and often where there is little or no soil; it is very common in the chinks between paving-stones in unfrequented places, and on the surface of the earth contained in garden-pots, as also upon walls which from any cause are kept constantly damp.

FIG. 6.—MARCHANTIA POLYMORPHA, one of the commonest of the Liverworts.

33. Besides the regular fructification, this little plant has a very curious apparatus, for the production of small leafy bodies, which may be regarded as buds, and which spontaneously separate from the parent structure and develop themselves into new beings. As these, when mature, are liable to be washed out of their receptacle by rain, and to be carried to different parts of the neighbouring surface, and as they grow very rapidly whilst supplied with moisture, the rapid extension of the plant under such circumstances is easily accounted for. The little receptacles of a basket-form, in which these are produced, may be generally seen in some stage of their growth, on the upper side of the leafy expansion of which the plant consists; and they constitute

beautiful objects for a low magnifying power of the microscope. The budlike bodies, having the form of flat disks, like coins, may often be seen to grow, whilst still contained in their receptacle, and even to graft themselves, as it were, on the parent plant.

34. The group of Cryptogamic plants termed *Lichens*, mostly consists of dry, hard, scaly crusts, destitute of leaves and stems, and even of anything bearing a resemblance to them; they grow upon bare walls, the trunks of old trees, and other such situations, in which they are much exposed to light, and not abundantly supplied with moisture. In their general structure they nearly approach to the Sea-weeds; and differ from them chiefly, in being adapted to live in air, instead of in water. The dry hard crust is usually of a greyish colour; its upper surface, being exposed to the light and warmth of the sun, performs the functions

FIG. 7.—SCALY LICHEN.

of leaves; whilst from beneath it there proceed a number of minute hair-like filaments, which serve both to fix it by clinging to the substance on which it grows, and also, it may be believed, for the absorption of fluid—the chief uses of the roots in the Flowering Plants. Lichens are among the slowest in growth of all plants, and the least subject to alteration from decay. Whilst alive, they scarcely exhibit any change through a long series of years; and when dead, their forms and colours are scarcely altered by being dried.

35. There can be no doubt, that the greater part of this tribe derive their nourishment from the atmosphere and its contained moisture alone; flourishing as they do upon sterile rocks, without a particle of soil or mould in their neighbourhood. There

are many species, which ordinarily grow upon the trunks of trees; and these are commonly spoken of as Mosses,—but incorrectly so. The shaggy appearance of the apple-trees of an old Orchard

FIG. 8.—LICHENS.

is in general entirely due to Lichens, although a few Mosses may sometimes be found among these. Of such Lichens, by far the greater part vegetate indifferently on all kinds of trees, and they flourish equally well upon a damp wall; so that there is no reason to suppose that they derive any more nutriment from the stems on which they grow, than is afforded by the moisture covering their surface. There is no doubt, however, that some trees are much more favourable to their growth than others. Thus, the Beech, Elm, Sycamore, and Lime, are comparatively seldom found infested with the common *Beard-moss*, which clothes so profusely the Fir, Ash, Oak, or Birch; so that the poet's epithet of "rude and moss-grown beech" is by no means appropriate.

FIG. 9.—PARMELIA PERFORATA, Lichen with projecting shields.

36. The fructification of the Lichens is not much raised above the general surface, but is usually im'edded in certain parts of it, somewhat differently formed from the rest, and termed *shields*. The early growth of these plants is favoured by darkness; but for the ripening of the reproductive bodies, a considerable quantity of light is required. The development of the shields, which takes place under its

influence, is frequently accompanied by so great a change in the general appearance of the plant, that the same species growing in dark and moist places, in which the früctification was not evolved, has been considered to belong to a distinct kind from the perfect specimen. No true Lichens are ever found in mines, caverns, or other places deprived of light; nor are there any that grow entirely under water; although some species, which connect this group with the Sea-weeds, grow on the sea-shore, where they are alternately submerged and left dry by the tide.

37. To the Lichens may well be applied the title of *Vernaculi*, or bond-slaves, which Linnæus fancifully gave to the Sea-weeds, regarding them as fettered to the rocks on which they grow. For the Lichens seem as it were chained to the soil, which they labour to improve for the benefit of others, although they derive no nourishment from it themselves. The mode in which they prepare the sterile rock, for the reception of plants that require a higher kind of nourishment, is most remarkable. They may be said to dig for themselves graves, for the reception of their remains, when death and decay would otherwise speedily dissipate them. For whilst living, these Lichens form a considerable quantity of oxalic acid, (which is a peculiar compound of carbon and oxygen, two ingredients supplied by the atmosphere, Chap. VI.); and this acts chemically upon the rock, (especially if of limestone,) forming a hollow which retains the particles of the structure, when their term of connected existence has expired. The moisture which is caught in these hollows, finds its way into the cracks and crevices of the rocks; and, when frozen, rends them into minute fragments by its expansion, and thus adds more and more to the forming soil. Successive generations of these bond-slaves continuously and indefatigably perform their duties; until at length, as the result of their accumulated toil, the barren and insulated rocks, or the pumice or lava of the volcano, become converted into fruitful fields. For when Flora's standard has once been planted on tracts thus claimed, they are soon colonised by plants of other tribes. The Mosses, Ferns, and other Cryptogamia follow them; and at last, by the growth and decay of successive generations of plants, a sufficient thickness of

soil is produced, for the nourishment of the luxuriant herbage, and the support of the lofty forest-tree. And thus, by the labours of these apparently insignificant plants, Men are enabled to reap their harvest, and to supply themselves with timber from forests, and cattle increase and multiply, on what was formerly but a naked and desolate rock.

38. One of Nature's truest though least attractive delineators, has thus faithfully described such a process, as it occurs on ruined buildings. It should be remarked, however, that the terms *seed*, *foliage*, and *flower*, are not strictly correct as applied to the Lichens, which have none of these.

"Seeds to our eyes invisible, will find
On the rude rock the bed that fits their kind;
There in the rugged soil they safely dwell,
Till showers and snows the subtle atoms swell,
And spread th' enduring foliage; then we trace
The freckled flower upon the flinty base;
These all increase, till in unnoted years
The stony tower as gray with age appears,
With coats of vegetation thinly spread,
Coat above coat, the living on the dead.
These then dissolve to dust, and make a way
For bolder foliage, nursed by their decay:
The long-enduring ferns in time will all
Die and depose their dust upon the wall:
Where the wing'd seed may rest, till many a flower
Shows Flora's triumph o'er the falling tower."

CRABBE'S *Borough*.

39. Besides this important office in the economy of Nature, some of the Lichens are peculiarly useful to man, on account of the valuable dyes they afford him. The blue dye termed Archil, or Litmus, which is changed to a bright red by the action of acids, is obtained from several species of Lichen growing in the Canary Islands and elsewhere; and many other species, not at present regarded, might probably be converted with advantage to the same use. To the Laplanders, the tribe of Lichens is of peculiar utility; indeed on it they depend for their subsistence. For though it is not an article of their own diet, a humble Lichen, commonly known as the Reindeer Moss, supplies the animal, on which they depend for almost all their means of ex-

istence, with food throughout their dreary winter; its vegetation not being checked by the snow beneath which it grows. A species of Lichen growing on the rocks of the Arctic regions of North America, has afforded subsistence for many days, to some of the adventurous explorers of that desolate country, when other provisions could not be obtained.

40. The group of *Algæ*, or Sea-weeds, includes the very lowest forms of vegetable organization; but it also comprehends some plants whose structure possesses great complexity. The Algæ may be considered as Lichens formed to exist in water; their general structure, and the arrangement of their parts, being much alike. The hard scaly crust of the Lichens, formed under the influence of the sun and air, and never attaining any great extent, seems to bear a remarkable contrast with the immense leaf-like expansions, composed of soft, easily decomposed tissue, presented by the Algæ; yet wherever any of the former group inhabit damp shady places, their character much approaches to that of the latter; and in regard to some plants, it is difficult to fix the group to which they belong. Although the term Sea-weed is that usually considered equivalent to Algæ, it should be understood that the class includes many species, which are inhabitants of fresh water. Of this kind are the *Confervæ*,—the long green hair-like filaments of which are almost constantly found attached to stones, at the sides or bottom of running streams. These are among the simplest forms of vegetation. Each filament consists of a single row of minute cells or vesicles, attached to each other end to end. Every one of these vesicles is capable of growing by itself, and of reproducing its kind; for at a certain period a minute orifice appears in its walls, from which issue forth some of the little green particles it contains; and these become the germs of new plants of the same description (Chap. XII.).

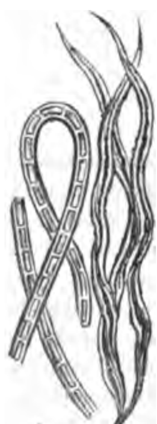

FIG. 10.—CONFERVÆ, with separate filament magnified.

41. The higher kinds of Algæ inhabit Sea-

water only. They often assume the forms of more perfect plants, presenting an appearance as of roots, stems, and leaves. But these parts have not those differences of structure which are characteristic of them when truly formed, and which will be hereafter described; on the contrary, they all consist of the same

SCHIZONEMA DILLWYNII. LAMINARIA SACCHARINA. FUCUS VESICULOSUS.

FIG. 11.

kind of simple and similar texture as that of the Confervæ;— the expanded leaf of a Sea-weed being composed, as it were, of a number of filaments of the Confervæ, laid side by side. The structure of these apparently different parts being thus so nearly the same, their functions or uses have an equal conformity; for the root-like fibres at the bottom of the stem, only serve to fix the plant to the rocks or stones, to which it is its habit to attach itself, instead of absorbing or sucking up nourishment as in the Flowering-plants. The cause of this difference is obvious. Where the *whole* plant is constantly immersed in the fluid, which affords it the materials of its growth, no one part of it need be specially endowed with the power: and it will be hereafter

shown (Chap. IV.) how strong the contrast is, between the functions of the true roots of Flowering-plants, and the root-like organs of the Algæ.

42. The higher Algæ sometimes attain a prodigious extent of development, forming vast submarine forests of the most luxuriant vegetation. Thus the *Chorda filum*, a species common in the North Sea, is frequently found of the length of 30 or 40 feet; and in the neighbourhood of the Orkneys, it forms meadows, through which a boat forces its way with difficulty. It grows in the form of a long and even cord (whence its name), about the size of a quill, attached at one end to the bottom or shore, and the rest supported by the water. This is nothing, however, to the prodigious extent of the *Macrocystis pyrifera*, which is reported to be from 500 to 1500 feet in length, the long and narrow fronds having an air-vesicle at the base of each, the stem not being thicker than the finger, and its upper branches as slender as common pack-thread. Another tropical species attains the length of 25 or 30 feet, with a trunk as thick as a man's thigh. Sometimes these stems are solid, and sometimes hollow; the tubular stem of one species of Laminaria, found near the Cape of Good Hope, has been used by the natives as a trumpet, when dried. Another species furnishes the natives of some parts of Australia, with a large proportion of their instruments, vessels, and even of their food.

43. The marine Algæ differ much in their habits. Some species grow altogether beneath the water, attaching themselves below the lowest tide-level. Others fix themselves where their fronds may float on the surface, and may be exposed in some degree to the direct influence of the air. Others again frequent a height, at which they are left dry at every retreating tide; and some are found in situations, in which they are scarcely ever covered by water, thus approaching in habits, and in character also, to the Lichens. Although most attach themselves to rocks or other solid masses, frequenting the shores or shallows rather than the open sea, there are some exceptions, among which one of the most remarkable is the *Sargasso* or *Gulf Weed*, which floats on the surface of the ocean, in the Gulf of Mexico, and in the current which sets from this towards the north. Immense

fields of it are seen by the navigator, extending as far as the eye can reach, and conveying the idea of rocks and shallows,—dangers far distant. It is sometimes so abundant, as seriously to interfere with the progress of the ship through the water; and it was this which alarmed the crew of Columbus, in his first voyage of discovery.

44. The distribution of different species through the ocean, is influenced by latitude, by the depth of water, and by currents, nearly in the same manner as the higher plants are affected by temperature, elevation above the sea level, and the conditions of the atmosphere as to dryness and calmness. Some species can thrive well under considerable variation in these conditions; whilst others are dependent upon certain states of them for their existence. The former, therefore, are extensively diffused, being found along many shores, whilst the latter are rarer, and only inhabit particular spots, in which these conditions are met with. Contrary to what might have been expected,—considering that the Algæ do not imbibe any nourishment by the spreading root-like fibres, which attach them to the solid masses of the shore,—it has been ascertained that they do not grow indifferently on all kinds of rocks; but that if, for example, along the same line of coast, there be an alternation of limestone and granite rocks, some species will attach themselves in preference to the former, and others to the latter. This curious fact can only be explained by the supposition, that small quantities of the mineral matter are dissolved by the water of the neighbourhood; and that in this manner they act upon the plant.

45. Of all tribes of plants, the Algæ are commonly reputed the least useful; in fact their inutility was proverbial among the ancients. Yet neither in regard to the general economy of nature, nor as to the wants of man, are they to be so considered. They supply food to a large number of marine animals, which browse upon them as those inhabiting the land do upon its most luxuriant pastures. Cattle have been very profitably fed on some species abundant on the northern shores; and even become so fond of this diet as greedily to seek for it. Many kinds,—such as the *Alaria esculenta*, called in Scotland badder-locks or honey-ware,—furnish a wholesome and palatable food for Man,

and are employed by the poorer classes along the shores of the north of Europe; whilst others are reckoned a luxury by the rich. The Laver of this country, the Carrageen, or Irish Bog Moss (as it is erroneously called), and other edible substances, belong to this group; and from other species of it, are formed the edible birds'-nests, which are considered so great a delicacy by the Chinese,—the best being sold for nearly their weight in gold. These nests are constructed by a bird resembling the Swallow, which reduces the Sea-weed in its stomach to a sort of gelatinous mass, before employing it for this purpose.

FIG. 12.—ALARIA ESCULENTA.

46. But all these uses are comparatively trifling, when the other modes in which the Algæ may be made beneficial to Man are considered. The *kelp*, from which until recently the glass-maker and soap-boiler derived most of the alkali which they required for their manufacture, is nothing but the ashes of Sea-weeds; which contain a large proportion of this substance, derived from the water in which they grow. Those most employed for this purpose, have been the *Fucus vesiculosus* and other species of Fuci, the *Chorda filum*, and several species of *Laminaria*. Other means of obtaining soda from sea-water have now partly superseded this; but until recently, it was almost the only method. The account handed down by tradition, of the mode in which glass was invented, whether it be itself true or false, serves to illustrate the properties of the Sea-weed. It is said that some sailors cast ashore by shipwreck, hav-

FIG. 13.—FUCUS VESICULOSUS.

ing kindled a fire on the sand, supplied it with some dry sea-weed as fuel; and that under the ashes, a mass of vitrified matter was afterwards found, resulting from the union at a high temperature, of the soda of the sea-weed, with the silex of the sand. Many Algæ also constitute a very valuable manure; and might be much more used than they are. But one of their greatest benefits to Man, consists in the Iodine with which they supply him; —a substance which is of the most important use to the Physician, in the treatment of many diseases, and which is a nearly certain cure for some, which were formerly considered almost irremediable. One species, moreover, which abounds on the shores of China, furnishes a glue and varnish to the Chinese, even superior to that which is obtained from animal matter in this country. It seems, when once dried, to resist the action of water; for it is employed to fill up the lozenge-shaped interstices in the network of Bamboo, of which windows are frequently constructed; as well as to strengthen and varnish the paper of their lanterns. A species abounding on the southern and western coasts of Ireland furnishes a good *size* for house-painters; and there are many others, which contain an amount of gelatinous matter, that might be rendered useful in various ways.

47. Besides the tribes of whose character a sketch has been thus given, there are others of a doubtful nature, which are generally referred to this group; although some peculiar characters which they exhibit, and their similarity to certain *animal* forms, render it doubtful whether they ought not to rank with that kingdom. They are mostly formed of cells jointed together, as the Confervæ; but some of them seem to possess a different interior structure; and others exhibit very curious motions, which can scarcely be distinguished with certainty from those of animals. In one of these groups, a large quantity of flinty matter is contained in the walls of the cells; so that they perfectly retain their form, after all the vegetable structure has been destroyed, by the action of heat and acids. The cavity of the cells, too, is sometimes seen to be partly occupied by large angular crystals. All the plants (if such they be) of this group are very minute.

48. There is, however, a group yet simpler than these, of the vegetable nature of which there is no doubt. On the damp parts

of some hard surfaces, is not unfrequently seen a greenish or reddish slime, which, when examined with the microscope, is found to consist of a number of minute cells, having little connexion with each other, but imbedded in a sort of jelly, which surrounds and connects them. On some minute variations between these simple plants, various distinctions have been formed; one is known under the name of *gory dew*, from its red colour; and another, which appears on the surface of snow, tinging extensive tracts with a deep crimson, is known as *red snow*. This sometimes appears so suddenly, and over so large a space, as to lead to the belief that it had fallen from the sky; but its growth and multiplication are so rapid as to leave no difficulty in accounting for its appearance.* This plant, which may be regarded as one of the simplest forms of vegetation, if not the very simplest, consists of a little bag or membrane, forming what is called a cell. A large number of these are commonly found together; but each one is separate from the rest, and is to be regarded as a distinct individual. It obtains its own nourishment, by absorbing the fluid around; and grows and comes to maturity, without any other support or assistance, than that afforded by the air and moisture, with which its surface is in contact. When come to maturity, a number of minute granules may be seen within it; these are the germs of new plants; and, when liberated by the rupture of the parent-cell, they go through precisely the same series of changes. This little plant will be often referred to, in illustration of the simplest conditions, in which the processes of the Vegetable economy can be performed. In its habits,—flourishing as it does only in very damp situations, though partly exposed to the air, —it must be regarded as belonging to the Algæ; but it bears a close correspondence with the lowest forms of a group that now remains to be considered; whose conditions of existence, however, are very different.

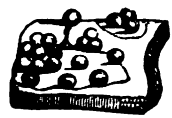

FIG. 14.—PROTOCOCCUS NIVALIS, or RED SNOW, highly magnified: showing its separate cells or vesicles partly imbedded in a slimy jelly.

* The Author is aware that recent discoveries have shown, that the Red Snow of some districts consists of Animalcules; but he is satisfied, from his own observations, of the real existence of the Plant here described.

49. In their general simplicity of structure, the *Fungi* (the tribe including Mushrooms, Puff-balls, and many kinds of blight, mildew, and mould), correspond with the Algæ and Lichens;

FIG. 15.—VARIOUS FORMS OF THE HIGHER FUNGI.

but they differ remarkably in habits, and in the character of their fabrics. Fungi will not grow with the simple nourishment which serves for *their* support; but require to be fed with decaying animal or vegetable matter of some kind; and they chiefly frequent situations, in which decomposition is going on with rapidity, and which are at the same time dark and warm. It is very remarkable to observe the constancy with which particular species make their appearance on particular substances. Thus, no fungus but the common edible Mushroom ever grows upon the mushroom-spawn (as it is called); though this does not necessarily contain its germs, being merely a kind of manure composed of various decaying substances, which prepares the soil to receive them from the atmosphere. Again, there is a species of mould which is only found on the surface of the dung of cats deposited in moist and obscure places. Almost every tribe of plants has its peculiar species of blight or rust, to the attacks of

which it is liable, and which differ from the kinds infesting nearly similar vegetables.

50. The universality of the appearance of the simpler kinds of Fungi,—such as mould, mildew, &c.—upon all spots favourable to their development, has given rise to the belief that they were *spontaneously* produced by the decomposing substances. But there is no occasion for this mode of accounting for it; since the extraordinary means adopted by Nature, for the production and diffusion of their germs, suffices to explain it. The duration of the lives of individuals among the Fungi is very brief; their tissue is soft and succulent, sometimes containing so little solid matter, as almost to melt away when broken down; and never possessing any considerable amount of firmness. Now in the Algæ, where we have seen the development of the individual taking place to such an enormous extent, the fructification is generally obscure, and sometimes even scarcely perceptible. But in the Fungi, all the energies of the plant seem directed to the production of the germs of new ones; its own size seldom attains any great extent; but the number of these germs is often almost incalculable. Thus, the fine dust which issues from the common Puff-ball when mature, consists entirely of these little bodies, which are diffused through the air, and seem to float about in it, ready to develop themselves when they meet with the fitting conditions. In a single Fungus, above ten millions have been counted; and these were probably by no means the whole number contained in it. When these minute germs are once spread through the air, there are so many means provided for their diffusion, that it is difficult to conceive of a place from which they should be excluded.

51. However improbable, then, it may at first sight appear, that every portion of the air we breathe should contain the germs of a large number of species of Fungi, ready to develop themselves whenever the peculiar conditions adapted to each kind are presented,—there seems good reason to believe, that such is the case; and in this manner we may account for several facts, of some practical importance, relative to the production of those very troublesome forms of vegetation, known by the names of mould, mildew, &c. It is well known that fruit-preserves are very

liable to be attacked by the common *bead-mould;* which no care employed in completely closing the mouths of the jars can prevent. It has been remarked, however, that they are much less liable to suffer in this way, if not left open for a night before they are tied down; and it is therefore probable, that the germs of the mould sow themselves, as it were, in this luxuriant soil, before the jar is covered. Again, there is a particular kind of cheese, much valued by some epicures, which derives its peculiar flavour from the quantity of fungous vegetation it contains. It is prepared simply by breaking up the curd, and exposing it for a day or two, in small lumps laid upon a cloth, to the sun and air; it there seems to receive the germs of Fungi, which afterwards vegetate in it, and spread their growth through the mass whilst it is yet soft.

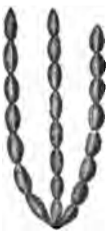

FIG. 16. COMMON BLUE MOULD greatly magnified: its stems consisting of single cells, loosely jointed together.

52. In all these instances, the Fungi derive their nutriment from organic matter, which is either already in a state of decay, or will readily decompose. There can be little doubt, that their development hastens decay when it is slow, or even causes decomposition in substances which previously exhibited none. Thus, a fruit-preserve, into which no *mould* finds its way, may remain sweet for many years; but the growth of the mould produces chemical changes in it, which are of a kind to supply the plant with the materials it requires. There is another very remarkable group of Fungi, which develops itself in the midst of the tissues of living plants and animals. To it belong, amongst others, the *mildew*, *rust*, *smut*, &c. of corn and other vegetables; these are distinct plants, having all the characters of true Fungi, but growing from the ears, stems, &c. of those they infest, so as to appear like a part of themselves. In fact the question has been raised, whether they are really produced from separate germs, or whether they are not diseased parts of the structure on which they appear. But there seems little doubt, that distinct germs are introduced from without. They can be communicated from one plant to another; and they may perhaps enter through the stomata or breathing-pores hereafter to be described

§. 91); though experiment shows it to be more likely, that they are conveyed in the water which drains through the soil, and

FIG. 17.—ÆCIDIUM CANCELLATUM; *a*, a leaf upon which it is seen growing of the natural size; *b*, peridia, magnified.

that they are introduced into the system with the fluid which is absorbed. In that case they must be almost immeasurably small; since it is known, that the minutest particles of any substance which can be artificially obtained, are usually rejected by the roots, as too large, when diffused through water which is being absorbed through their pores.

53. Animals are liable, as well as plants, to the growth of Fungi within their bodies. There is a species of Wasp in the West Indies, of which individuals are often seen flying about with plants of their own length, projecting from some part of their surface; the germs of these having been originally introduced, probably through the breathing pores at their sides, (ANIM. PHYSIOL. §. 320), and taking root, as it were, in their substance, so as to develope a luxuriant vegetation. In time, however, the fungous growth spreads through the body, and destroys the life of the insect; and it then seems to grow more rapidly, the decomposing tissue of the dead body being still more adapted than the living structure, to afford it nutriment.

54. A very curious example of the growth of Fungi within the living animal body has lately been detected; and the knowledge of it has proved of great importance. The Silk-worm breeders of Italy and the South of France, especially in particular districts, have been subject to a considerable loss, by a disease termed *Muscardine*, which sometimes attacks the worms in large numbers, just when about to enter the chrysalis state. This disease has been ascertained to be due to the growth of a minute vegetable of the Fungus tribe, nearly resembling the common mould, within their bodies. It is capable of being communicated to any individual from one already affected, by the introduction beneath the skin of the former, of some particles from the diseased portion of the latter; and it then spreads in the fatty mass beneath the skin, occasioning the destruction of this tissue, which is very important as a reservoir of nourishment to the animal, when about to pass into a state of complete inactivity. The plant spreads by the extension of its own structure; and also by the production of minute germs, which are taken up by the circulating blood, and carried to distant parts of the body. The disease invariably occasions the death of the Silk-worm; but it does not show itself externally until afterwards, when it rapidly shoots forth from beneath the skin. The Caterpillar, Chrysalis, and Moth are all susceptible of having the disease communicated to them, by the kind of inoculation just described; but it is only the first which usually receives it spontaneously. The importance of this disease to the breeders of silk-worms, led, as soon as its true nature was understood, to careful inquiry into the circumstances which favour the production of the fungus; and it has been shown that, if the bodies of the caterpillars, which (from various causes) have died during breeding, be thrown together in heaps, and exposed to the influence of a warm and moist atmosphere for a few days (as has been very commonly the case), this fungus almost invariably appears upon them, just as other kinds of mould appear on other decaying substances; and that it is then propagated to the living worms, by the diffusion of its germs through the atmosphere. The knowledge of this fact, and the precautions taken in consequence, have greatly diminished the mortality.

55. Another very curious example of vegetation of a fungous character, in a situation where its existence was not until recently suspected, is presented in the process of fermentation. It appears from microscopic examination of a mass of *yeast*, that it consists of a number of minute disconnected vesicles, which closely resemble those of the Red Snow, and appear to constitute one of the simplest possible forms of vegetation. These, like seeds, may remain for almost any length of time in an inactive condition, without losing their vitality; and their power of growing, when placed in proper circumstances, is not destroyed by their being entirely dried up, nor by their being exposed to such extremes of temperature, as the boiling point of water and seventy-six degrees below zero. When these bodies are placed in a fluid, in which any kind of sugary matter is contained, they commence vegetating actively, provided the temperature be sufficiently high; and the decomposition which they effect in the fluid, the nature of which will be presently explained, is that which constitutes its *fermentation*.

56. If a small portion of a fluid in this state be examined at intervals, with a powerful microscope, it is observed that each of the little vesicles contained in it puts forth one or more prolongations or buds, which in time become new vesicles like their parents; these again perform the same process; so that, within a

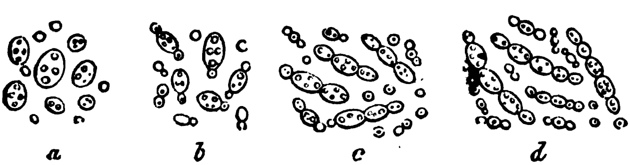

FIG. 18.—DIFFERENT STAGES OF THE VEGETATION OF YEAST; *a*, single cells of which it at first consists; *b*, cells with buds; *c*, the same more advanced; *d*, rows of cells corresponding to those of Fig. 9.

few hours, the single vesicles have developed themselves into rows of four, five, or six. This is not the only way, however, in which they multiply; for sometimes the vesicles are observed to burst, and to emit a number of minute granules, which are the germs of new plants, and which soon develop themselves into

additional cells. By the time that five or six vesicles are found in each group, the fermentation is sufficiently far advanced for the purposes of the brewer; and he then takes measures to check it, by which the vegetation of the yeast is suspended. The groups of vesicles then separate into individuals, resembling those which first constituted the yeast; and thus a greatly-increased amount of this substance is the result of the process.

57. The process of fermentation consists, as regards the fluid, in the conversion of the solution of sugar, into alcohol or spirit of wine; and this is effected by the action of the vegetating fungus, which withdraws from the fluid, for the supply of its own growth, that portion of its elements which constitutes the difference between sugar and alcohol. A process very similar to this takes place when the common Mould, growing upon the surface of a sweet preserve, causes its fermentation. The little plant bears considerable resemblance to the Red Snow; but differs from it in the two following important particulars.—The Red Snow can flourish, when supplied with air and moisture alone,—the conditions which have been mentioned as favourable to the growth of the Algæ; whilst this Yeast-plant can only grow in the solution of vegetable matter, which is ready to undergo decomposition, and which yields it a kind of nutriment that the Red Snow does not require, but which is necessary for the growth of all the Fungi. This is an instance, then, of what was formerly stated, respecting the close resemblance between the lowest forms of these simple tribes, which differ from one another more in the conditions necessary for their respective growth, than in their own structure.—The other point of difference consists in the extension of the Yeast-plant by buds, that is, by the formation of new cells as continuations from the old ones, as well as by the formation of separate germs; whilst the Red Snow is propagated by the latter only. It is interesting to trace, in a being so extremely low in the scale, the two kinds of Reproduction, which are performed in a manner so much more complex, and apparently so different, in the higher plants.

58. The growth and reproduction of the more complex kinds of Fungi, differs in no essential particulars, from the correspond-

ing processes in the lowest and simplest. In the *Bead-mould* (Fig. 16), every cell of which the little stems are composed, lives for itself alone; and, like that of the Yeast-Plant, it may either develop new cells from its extremities, by a process resembling budding, or it may burst and set free a multitude of contained germs, each of which may become a new cell. This process very much resembles that which takes place in the Conferva (§. 40). But in the higher Fungi, as in the higher Algæ, we find a certain set of cells set apart for reproduction, and contained in a distinct portion of the plant. This is the case, for example, in the common Puff-ball, in which the reproductive cells or spores are enveloped by a distinct membrane, which sets them free, in the form of fine dust or smoke, by bursting when they are mature. Nearly the same conformation exists in the *Æcidium* (Fig. 17), and in other plants resembling it; in these, the membranous envelope, which encloses the spores, and discharges them by an orifice in its side or summit, is termed the *peridium*. A still higher form is seen in the Agaric or Mushroom tribe; of which a specimen is represented in Fig. 19. Here we have a stem, *a*, with rootlets at the base, by which the plant imbibes its nutriment; at its upper extremity, it bears the *pileus* or cap, *b*; and on the under side of this are seen the *gills*, *c*, which radiate from the centre towards the circumference. These are composed of a membrane in which

FIG. 19.—AMANITA MUSCARIA.
a, the hollow stripes or stem; *b*, the pileus or cap; *c*, the lamella or gills; *d*, the volva or wrapper; *e*, the velum or veil.

the reproductive cells are imbedded. At an early period of its development, the pileus is folded down upon the stem, and is inclosed in a membrane termed the *volva* or wrapper, the remains

of which, after it has burst, are seen at *d*. Agarics in the various stages of their development, are represented in the upper part of Fig. 15.

59. Of all the Cryptogamia, the Fungi are the most important to Man; and their influence seems at first sight exerted rather to his injury, than to his benefit. Those minute species which constitute mildew, blight, rust, &c., often destroy, to an immense amount, the fruits of the earth, upon which he relies for his chief support. An instance has been just recorded, in which the lives of animals that administer to his luxury, are also destroyed in large numbers. The decay of timber in the mode commonly termed *dry-rot*, is caused by the growth of Fungi; of which several species are frequently concerned in effecting this most injurious process. The ravages which they commit in ships, and in every kind of wooden structure, as soon as a settlement is made, can only be conceived by those who have witnessed and examined them. The devastations they have committed in our navy and merchant vessels, excited attention to the subject; and led to the invention of the process, now known by the name of *Kyanising** (from the name of its inventor); but their destruction of house timbers is quite as rapid and complete, though less common. "I knew a house," says Mr. Burnett, "into which the rot gained admittance, and which, during the four years we rented it, had the parlours twice wainscotted, and a new flight of stairs; the dry-rot having rendered it unsafe to go from the ground-floor to the bed-rooms. Every precaution was taken to remove the decaying timbers when the new work was done; yet the dry-rot so rapidly gained strength, that the house was ultimately pulled down. Some of my books which suffered least, and which I still retain, bear mournful impressions of its ruthless hand; others were so much affected, that the leaves resembled tinder, and, when the volumes were opened, fell out in dust or fragments." The decay of the wood seems partly due to the

* This process consists in soaking the wood or other material in water, in which corrosive sublimate has been dissolved; and in this manner, a change is effected, which seems to deprive the germs of Fungi of the power of obtaining nutriment. The substance termed Kreosote has been lately employed for the same purpose, with very successful results.

growth of the Fungi in its substance, which is decomposed by it, as are the fluid and half-solid matters already spoken of; and partly to the moisture, which they are the means of introducing into its interior. The germs of these plants fall into the chinks of the timber, where they take root; and in their growth, they greatly widen these chinks, and thus give admission to moisture from without, as well as to a new set of these minute germs, which may prove even more destructive; and by a continuance and repetition of these processes, the whole strength of the timber is at last destroyed.

60. The power of expansion which these plants possess, soft as their tissues seem, is truly wonderful. Some years ago the town of Basingstoke was paved; and not many months afterwards, the pavement was observed to exhibit an unevenness, which could not be easily accounted for. In a short time after the mystery was explained; for some of the heaviest stones were completely lifted out of their beds by the growth of large toadstools beneath them. One of these stones measured twenty-two inches by twenty-one, and weighed 83 lbs.; and the resistance offered by the mortar which held it in its place would probably be even a greater obstacle than the weight. It became necessary to re-pave the whole town, in consequence of this remarkable disturbance.

61. But although in these and many other ways, Fungi are injurious to Man, the benefits they confer upon him far outweigh their occasional devastations; and it is only through the constancy of the former that they are overlooked and unappreciated. It is not only to Man that they are of the most essential service, but to the whole Animal kingdom. To Fungi may be justly applied the designation, which has been conferred upon Insects, that of the "scavengers of nature;" for, like insects, they labour with the most astonishing effect, in the removal of refuse and decaying substances, which, were they left upon the surface of the earth, would prove not merely useless tenants, but injurious incumbrances. Their vapour-like germs float about in the atmosphere, in countless myriads, only waiting for the presence of a fitter soil, on which to alight and grow. As long as there is no refuse decomposing matter to be removed, these spores remain inactive

and undeveloped, ("the scavengers are unemployed"); but as soon as any quantity, large or small, of decaying animal or vegetable matter, is left exposed, it is soon covered with a deposition of spores, which rapidly develop themselves into Fungi of various kinds.

62. Their astonishing fertility, and the rapidity with which they arrive at maturity, are among the most remarkable characters of this tribe of plants. Of the former, some account has already been given. Of the latter many instances are recorded. Thus one species has been known to attain the weight of 34lbs, in six weeks; and on the continent, Fungi of the same tribe have grown to upwards of 100lbs., having begun from a point not perceptible to the naked eye. A large fungus of the Puff-ball tribe has been seen to grow in one night, from a minute speck, to the size of a large gourd. No other living beings have powers of growth at all to be compared to this. The more rapid the decomposition, and the greater the quantity of noxious exhalations which would thus be spread through the atmosphere, the greater is the tendency to multiplication and luxuriant growth, in these humble plants, to which such exhalations serve as the most appropriate food.

63. Hence what has been said by Naturalists of Insects, applies with equal truth and force to these humbler tribes; and we may adopt, with slight modification, an interesting statement, which has been given of the agency of Insects, as a striking delineation of the operations of the Fungi.

64. "The peculiarity of their agency consists in their power of suddenly multiplying their numbers, to a degree which could only be accomplished in a considerable lapse of time, by any larger beings; and then as instantaneously relapsing, without the intervention of any violent disturbing cause, to their former insignificance. If, for the sake of employing on different but rare occasions, a power of many hundreds or thousands of horses, we were under the necessity of feeding all these animals at a great cost in the intervals, when their services were not required, we should greatly admire the invention of a machine, such as the steam-engine, which should be capable at any moment of exerting the same degree of strength, without any consumption of food during the periods of inaction; and the same kind of admi-

ration is strongly excited, when we contemplate the powers of Insect and Fungous life, in the creation of which Nature has been so prodigal. A scanty number of minute individuals, only to be detected by careful research, and often not detectable at all, are ready, in a few days or weeks, to give birth to myriads, which may repress or remove the nuisances referred to. But no sooner has the commission been executed, than the gigantic power becomes dormant; each of the mighty host soon reaches the term of its transient existence; and when the fitting food lessens in quantity, when the offal to be removed diminishes, then fewer of the spores find soil on which to germinate; and when the whole has been consumed, the legions before so active all return to their latent unnoticed state,—ready, however, at a moment's warning again to be developed, and, when labour is to be done again, again to commence their work, either in the same districts, or to migrate in clouds like locusts to other lands. In almost every season there are some species, but especially in autumn there are many, which in this manner put forth their strength; and then, like the spirits of the poet, which thronged the spacious hall, 'reduce to smallest forms their shapes immense.'"

65. Among the uses of Fungi to Man, their service as food must not be forgotten. In chemical composition they closely resemble animal flesh; and, accordingly, those of them which are free from injurious properties, furnish a highly nutritious article of diet; and some of the rarer species are greatly valued as dainties by the epicure. There is much difficulty, however, in distinguishing the innocent from the noxious species of Mushroom; and many fatal accidents have occurred from the employment of the poisonous kinds. Amongst the Fungi remarkable for their peculiar properties, may be mentioned one which is of great service, from its astringent properties, as a styptic, to check the flow of blood; and another which has the power even when dry, of producing a curious kind of intoxication, and which is used for that purpose by the Tartars. This is the species represented in Fig. 19. It is occasionally found in great abundance in this country; and is distinguished by the bright red hue of its upper surface, which is studded with white spots.

CHAPTER III.

OF THE ELEMENTARY STRUCTURE OF PLANTS

66. When we examine yet more closely, into the conformation of the different parts, of which an organised structure is composed, we find that, though the several organs are variously constructed, and are adapted for different offices or functions, they are built up, as it were, of the same materials. With the same bricks, stones, mortar, and timbers, a church, a palace, or a prison may be reared. Just so is it in organised structures. We do not find that each organ is entirely different from the rest, though it has usually something peculiar to it; but we are enabled to separate it into many distinct portions, something similar to which, if not exactly correspondent, may be recognised in other parts, Thus, for example, it was formerly stated, that the leaf consists of a midrib and veins proceeding from it, a fleshy substance filling up the interstices, and a cuticle or skin covering the whole. Now the midrib and veins, as well as the footstalk of which these are a prolongation, consist of three kinds of structure;—*woody fibre*, to which they owe their toughness, and by which they are adapted to give support to the softer structures;—*ducts* or canals, for the transmission of fluid;—and *spiral vessels*, which are designed to convey air. On tracing these to the stem, it will be found that they all exist in it under the same form, and that these portions of the leaves are in reality but continuations of it. Again, if we examine the fleshy substance which lies amongst them, we shall find that it corresponds very closely in character with the pulp of soft fruits, or the pith of the stem. And if we strip off the cuticle and investigate its structure, we shall perceive that it is but another form of the same kind of substance, and that it corresponds with the skin which

covers all the newly-formed parts of the stem and branches, as well as the various parts of the flower, and even the roots.

67. These several kinds of structure are termed the *primary tissues*, being the elements, as it were, of which the edifice is built up; and they are to the vegetable fabric what the bones, muscles, fat, blood-vessels, nerves, skin, &c. are to the animal.

68. Even these primary tissues may be regarded as consisting of other parts still more simple,—namely, *membrane* and *fibre*. The fleshy portion of the leaf, for example, or the pulp of fruits, consists of a number of little bags adhering together: each bag or vesicle consisting of a delicate membrane, without any perceptible orifice, and containing fluid. The membrane which incloses an egg after the shell is removed, will afford a good illustration, on a large scale, of the nature of these vesicles; they may, however, be readily distinguished and separated in an over-ripe orange, where they are of considerable size. The membrane which composes their walls may be regarded as one of the very simplest forms of vegetable tissue.—Again, if the stalk of a strawberry or geranium leaf be carefully cut *round* but *not through*, and the two parts be then pulled asunder for a short space, a number of glistening fibres, of extreme delicacy, will be seen running from one portion to the other. If these be put under the microscope, it will be evident that they had lain in spiral coils, which are partially straightened when they are thus drawn out, just as when a spiral spring is strained. These were coiled within the membranous tubes, that constitute the external sheath of the spiral vessels, which have been mentioned as existing in the leaf-stalk; and thus we are able to separate these vessels into the two other elements, *membrane* and *fibre*. These very minute delicate spiral fibres must not be confounded with the woody fibre, of which mention has been made, and the nature of which will be presently explained.

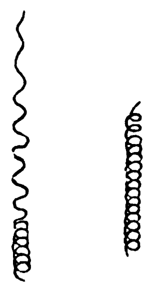

FIG. 20.—SPIRAL FIBRES DRAWN OUT.

69. The delicate *Membrane*, of which, in combination with

fibre, all the tissues of plants may be regarded as consisting, when they are newly formed, is of variable thickness and transparency In general, however, it is quite sufficiently transparent, to allow the colour of fluids in contact with it to be distinguished on the other side; and accordingly, though itself colourless or nearly so, it often appears tinged, in consequence of the cells or vessels which it forms, being filled with coloured fluid. Thus the cells of leaves appear green, those of the parts of flowers yellow, blue, red, &c.; not because that colour exists in the membrane of which they are composed (which, if they could be emptied, would appear almost colourless), but on account of the minute colouring particles diffused through their contained fluids. One of the most remarkable properties of vegetable membrane, is its power of allowing fluids to pass slowly through it, even though no visible pores or apertures can be detected in it. Occasionally the appearance of such apertures exists, when membrane is highly magnified; but this appearance is sometimes produced by grains of semi-transparent matter sticking to it; and is sometimes due to that portion of the membrane being thinner than the rest, through the deposition of new matter upon certain points, subsequent to the first formation, of which several examples will be presently given.

70. Elementary *Fibre* may be compared to hair of extreme delicacy; its diameter often not exceeding the 1-12,000 of an inch. It is generally transparent and colourless, and is usually disposed in a spiral direction. Its peculiar property is elasticity, combined with a degree of firmness, which, for its diameter, is very considerable. Accordingly we find its chief use to be, the keeping open, like an interior spring, the delicate membranous tubes through which air is to pass, and the preventing these from being pressed together by the growth of neighbouring parts. Not unfrequently, however, it seems less elastic than usual, and is broken during the processes of growth, into several smaller fragments; which then exhibit a peculiar tendency to grow together, in various irregular forms. In this way, several peculiar kinds of tissue are produced, which will shortly be noticed.

71. The one most universally present, no kind of plant being

without it in some form or other, and many being entirely composed of it, is that called *cellular* tissue, from its being made up of a number of separate cells, or minute bags, adherent together. These, when first formed, are usually nearly globular, or of a figure resembling an egg; so that, if cut across, their walls would exhibit a series of circles touching each other at certain points (Fig. 21, *a*). Afterwards, however, they are gradually pressed against each other, and their sides become flattened. Their form will then depend upon the amount of the pressure on the respective sides. If it have been equal in all directions, the cell will sometimes be cubical, as it is often found in pith (Fig. 21, *b*); or it will have the form termed the dodecahedron, which is a solid having twelve equal sides (Fig. 22). But if it be pressed more on one side than another, it will be narrowed in that direction, and elongated in the other. Thus the original form of the cell may become greatly modified, during the growth of the plant. In general, the greatest elongation takes place in the direction of most rapid increase; but this is not always the case; for in the stems of most trees in this climate, there is a peculiar set of cells extending from the pith towards the bark, which have their greatest length in a horizontal direction; and the cells being of an oblong flattened form, and arranged like bricks in a wall, this kind of structure has been called *muriform* (wall-like) cellular tissue (Fig. 21, *c*).

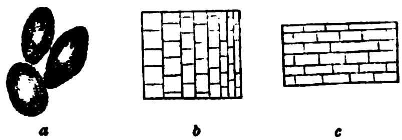

FIG. 21.—VARIOUS FORMS OF CELLULAR TISSUE; *a*, separate vesicles of an egg-shaped form; *b*, section of cubical cellular tissue of pith; *c*, section of muriform cellular tissue.

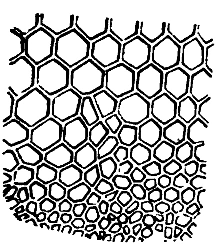

FIG. 22.—SECTION OF IRREGULARLY COMPRESSED CELLULAR TISSUE; the honey-comb appearance of the greater part is due to the 12-sided form of the cells, the walls of which, when cut across in any direction, present hexagons or 6-sided figures.

72. From what has been said of the *permeability*, or power of giving passage to fluids, which vegetable membrane possesses,

it may be inferred that this power is also possessed, by the simple modification of it just described. Accordingly we find this to be the case,—fluids being conducted through cellular tissue very readily from one part to another: but still it affords a sufficient degree of resistance, to cause the transmission of fluids most readily in the direction of the greatest length of the cells, where, of course, there will be the fewest partitions in a given space. Thus, therefore, fluids absorbed at the bottom of a stem, will pass upwards through its cellular tissue more readily than in any other direction,—except in the case of the *muriform* cellular tissue, which conducts fluids horizontally with the greatest readiness. The object of these peculiar adaptations will be more fully described in Chap. VI., where the structure and offices of the different parts of the stem will be severally detailed.

73. In the fabric of the lowest tribes of Plants, such as Sea-weeds, Lichens, the Fungi (or Mushroom tribe), Liverworts, and Mosses, little besides cellular tissue and its simple modifications can be found; and it forms a large proportion of the structure of even the highest tribes. Thus in every Plant, the leaves, flowers, bark, pith, and fruit, consist almost entirely of cellular tissue; and it is even found in the woody part of the stem and roots, besides forming the largest proportion of those soft succulent stems, which are only of short duration, dying as soon as the fruit they bear has ripened. The whole of the young plant, too, even of the highest tribes, consists, like the permanent forms of the lower, of this kind of structure. It is only when the true leaves have been unfolded, and are actively performing their functions, that the other kinds of tissue show themselves. In all newly-forming parts, also, the foundation, as it were, is laid with this tissue, in which the others subsequently appear. So universally is it present, even in the adult fabric, that, if it were possible to abstract all the others from it, the original form would still be retained, except where it would give way with its own weight.

74. But, although cellular tissue is, in its regular state (of which the pith of young twigs, or the pulp of fruits are characteristic examples), soft and spongy in its character, it does not

always remain so, but often acquires considerable hardness. This is the case, for example, in the *prickles* of the Rose and other plants, which are merely connected with the cuticle, and are not prolonged from the wood beneath. It is the case also in the *stones* of the Plum, Peach, Cherry, &c.; and in the gritty matter in the centre of the Pear. In all these parts, the processes of vegetation are no longer going on; but the power of firm resistance is required in their place. This is effected, by the deposition of solid matter within the cells. Sometimes the new product lies in regular layers, one within another, covering the whole membrane; sometimes it is deposited in what appears a less regular manner, certain points of the membrane being left uncovered by it. In this last case,

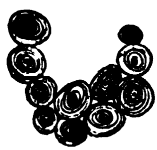

FIG. 23. — ROUND CELLS THICKENED BY INTERNAL DEPOSITS ARRANGED REGULARLY IN CIRCLES.

however, an additional object is attained; for the cells, though the greatest part of their walls is so much thickened, are still in a degree permeable to fluid, through the spots of the membrane on which no deposit has taken place. These spots in the walls of contiguous cells generally correspond with each other; so that fluids can find their way from one cell into the cavities of the neighbouring ones, though so large a proportion of their contents has become solid. When the walls of cells have been thus strengthened in particular parts, the membrane has a *dotted* appearance; the thinnest portions seeming almost like perforations.

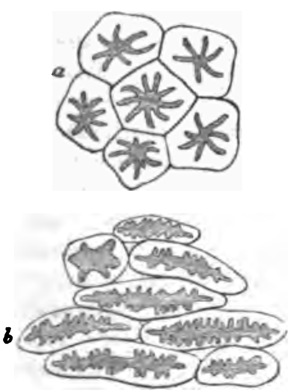

FIG. 24.—SECTIONS OF CELLS STRENGTHENED BY INTERNAL MATTER IRREGULARLY DEPOSITED; the shaded portion indicates the remaining cavities: *a*, cells from the gritty centre of the pear; *b*, cells from the stone of the plum.

75. The size of the cellules of this tissue is extremely variable; they are usually from 1-300 to 1-500 of an inch in diameter; but may be found of all sizes, from 1-30 to 1-3000 of an inch. One

of the most interesting modifications of it, is found in the Sphagnum or Bog-Moss; and in the coverings of some seeds. This consists in the presence, within the membranous wall of the cell, of a spiral fibre, coiling from one end to the other. In some of the seed-coats in which these spiral cells exist, the *membrane* of the cells is so delicate as to be easily dissolved away; so that, if a portion be put into water, the fibres spring out very beautifully by their own elasticity.

76. The next form of elementary tissue to be described, is that called *Woody Fibre*. It has received the name of *fibre*, because it always exists in an elongated form, and several of the tubes of which it consists, adhere together continuously, so as to form cords. This is seen in the common flax thread, for example. If the finest thread that could be separated with the naked eye, were submitted to a microscope, it would be seen to consist of several other fibres adhering together; none of these have any great length; but by the manner in which they adhere, side by side, and end to end, a continuous cord is produced. Each of these minute fibres, when more closely examined, is seen to consist of a slender transparent tube, tapering to a point at each end. It thus resembles a greatly elongated cell. It differs from cellular tissue of similar form, in the much greater strength of the membrane forming the walls of the tubes; though it is at the same time thinner. There are many intermediate forms, however, between one and the other. Woody fibre is evidently destined to convey fluid in the direction of its length, and is easily permeated by it. Minute openings have sometimes been detected, in the points of the tubes, so as to connect one cavity with another, and thus to render the passage of fluid more easy. It is, however, especially destined to give firmness and elasticity to the parts of the structure which require support; and we almost constantly find *vessels* protected by it, wherever they exist.

FIG. 25. BUNDLE OF WOODY FIBRE.

77. In all plants with permanently-elevated stems, this tissue is very abundant in the adult state. It forms a large proportion

of the wood of the stem and roots; it partly composes the leaf-stalk, midrib, and veins of the leaves, and may even be traced in flowers; to many fruits, also, it imparts firmness and consistence. When no longer required for the conveyance of fluid, additional firmness and toughness are given to it, as to cellular tissue, by the deposition of various secretions within its tubes; and it is in the presence or absence of these, that the difference exists between the heart-wood and sap-wood of a trunk (§. 131). The woody tubes of the former are entirely choked up with the hard matter deposited in their cavities; and the sap rises through the latter only. This hardened tissue may be in some degree compared to the cartilage or gristle of animal bodies.

78. A peculiar form of woody fibre is found in the stems of resinous woods, especially the Pine and Fir tribe. The diameter of its tubes is much greater than that of any other woody tissue; and they alone perform the office of transmitting the sap upwards through the stem; the wood of these trees being destitute of the ducts or canals (presently to be described), which in other kinds of trees assist in this function. But it is by a peculiar set of dots seen along their course, that these woody tubes may be readily distinguished from all others. These dots appear to be produced, by the formation of certain little bodies *between* the adjacent tubes; and as the tubes are closely pressed together, these bodies (the nature of which is not certainly ascertained) project into the cavities of the tubes between which they lie. Whatever be their character, they are of great interest, as aiding to establish the true nature of Coal.

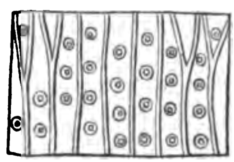
FIG. 26. — GLANDULAR WOODY FIBRE OF A DEAL SHAVING.

79. That this substance had a vegetable origin, has long been generally admitted; but from the comparative frequency and perfection with which the remains of Ferns occur in it, it has been supposed to have been produced by the decay of vast forests of this tribe of plants. As Ferns do not form resins, however, this hypothesis would not account for the large quantity of bituminous matter which coal contains; and hence it was supposed that coal

must have been formed from resinous woods, even though the remains of such were very scanty and imperfect. Now on applying the microscope to transparent sections of such fragments of coal, as most distinctly exhibit the fibrous structure, it is seen that they present the character which has been described, as peculiar to the resinous woods,—the *glandular* form of woody fibre, as it is technically termed; and hence it is established beyond doubt, that the immense masses of coal which now contribute so much, in every way, to the comfort and the social improvement of the human race, are but the remains of vast forests, probably the growth of many successive centuries, which chiefly, if not entirely, consisted of trees of the Pine and Fir kind. It is even possible, by the peculiarities of the arrangement of the dots, to say which of the subdivisions of that tribe at present existing, those primeval trees most nearly resembled. The reason why the remains of Ferns have been so well preserved, whilst those of other plants and trees should have lost all definite structure, has been already explained (§. 26).

80. The third kind of primary tissue, is that denominated the *Vascular*. Its typical form is the Spiral Vessel, which is only found in Flowering-Plants; but modifications of this exist in the lower tribes. The essential character of the Vascular tissue is the possession of a spiral fibre, coiling more or less regularly within its thin membranous tubes, from one extremity to the other. The true *spiral vessel* much resembles the woody fibre in form, being a long narrow tube drawn to a point at both ends. But the membranous wall is much thinner, and is easily torn asunder. The spiral filament is usually single; it is sometimes, however, double, or even triple; and in the very large spiral vessels of the Chinese Pitcher-Plant (Nepenthes, §. 242) it is quadruple. These tubes in their perfect state contain air only, which finds its way from one to another, like fluid through the woody tubes. They

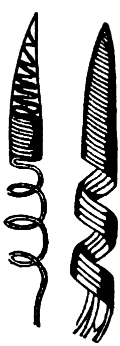

FIG. 27. — PORTIONS OF SPIRAL VESSELS: *a*, common form, with single fibre partly drawn out; *b*, from Nepenthes, with the quadruple fibre.

are found in the leaf-stalks, from which their spiral fibres can be uncoiled in the manner already described. They are found also in a delicate membrane, surrounding the pith of stem which possess one (§. 135); and in the midst of the woody bundles which form the *strings* of such stems as the Asparagus. From this plant, indeed, they may be obtained more readily, perhaps, than from any other. If a stem be boiled, or softened by soaking in water for some time, and these bundles be separated from the soft tissue which surrounds them, the parts of each may be further separated from each other, by rubbing them, with a little water, between two plates of glass. On looking at them with a magnifying-glass, some portions of these bundles will be seen to present a dark appearance, if still under water. This is caused by the air they contain; since bubbles of air in fluids viewed with the microscope, will appear dark to the observer, for reasons which will be mentioned in the Treatise on Light. If one of these threads be then carefully torn, with a pair of small needles fixed in handles, into finer ones, whilst under a powerful single magnifier, it may be separated into the individual spiral vessels which compose it, just as the thread of flax may be resolved into its woody tubes.

81. It is an interesting circumstance, that the air-tubes of Insects are formed upon nearly the same plan with these spiral vessels of Plants. The former consists, like the latter, of an external membrane, which is maintained in its tubular form, in spite of pressure from without, by the elasticity of a fibre, spirally coiled in its interior. The principal difference between the two structures is, that the air-tubes of Plants are closed vessels, and that their contents find their way gradually from one to another, permeating the delicate membrane of their walls; and that they give off, therefore, no branches: whilst the air-vessels of Insects, whose office it is to convey air with great rapidity into all parts of the structure, form a set of continuous tubes, which branch and ramify with the most wonderful minute-

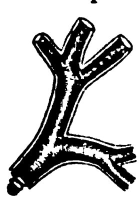

FIG. 28.
BRANCHING AIR-VESSEL OF INSECT.

ness, even in the smallest organs of the smallest Insect (ANIM. PHYSIOL. §. 320).

82. There are other kinds of tissue which must be classed under the same head, but which do not serve the same purposes, or possess the same structure. Instead of tubes drawn to a point at each end, we not unfrequently meet with long continuous cylindrical canals, which serve for the conveyance of fluid, instead of for the passage of air; these are called *Ducts*. There are several varieties of them; of which those will be first described, which evidently belong to the type of Vascular tissue. In Ferns (which have no true spiral vessels), we find Ducts, which very closely approach the spiral vessel in character; having an unbroken coil of spiral fibre throughout their whole extent; but, besides the important difference that these Ducts, are long continuous tubes, they are further distinguished by the brittleness of the spire, which snaps if we attempt to unrol it.

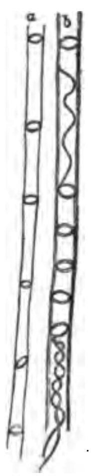

FIG. 29. DUCTS WITH INTERNAL FIBRE: *b*, spiral, with rings at intervals; *a*, annular throughout.

Such ducts are found in many other plants, and may be easily distinguished in the leaf-stalk of the Rhubarb. Another interesting modification of the spiral, is what is termed the *scalariform* or ladder-like duct; this also consists of a spiral fibre inclosed in a membrane, but has a space intervening between each turn of the spiral, so that the inner wall of the membranous tube is not entirely covered by it, but seems crossed by a series of bars.—There are other ducts, again, in which the spiral is irregular,—the coil sometimes terminating in a ring, and then commencing again, with perhaps the intervention of two or three rings (Fig. 29, *b*). Here it would seem, as if the membrane had grown faster than the spire could follow it; so that the fibre, not being elastic, had been occasionally broken.—In other ducts, again, we find no traces of a *spiral* fibre; but the membranous walls are distended by rings at intervals sometimes tolerably regular. These are called *annular* or ringed vessels (Fig. 29, *a*). The transition from the spiral to the annular vessels is

well seen, in the bundles of Vascular tissue in the petiole of the leaf of Ground-Ivy and other plants.

83. These two forms are especially interesting, from the analogies which can be found to them in the Animal structure. The close correspondence between the spiral vessels, and the *tracheæ* or air-tubes of Insects, has been already pointed out. On the other hand, the annular duct corresponds with the wind-pipe of higher animals; the membranous walls of which are prevented from falling together, by means of rings of cartilage disposed at regular intervals. And the half-spiral half-annular duct, which is the intermediate form in plants, precisely corresponds with the structure of the wind-pipe of the Dugong (one of the Whale tribe), in which we find a *spiral cartilage*, terminating at intervals in rings.

84. There are other forms of ducts, again, in some parts of which the traces of the spiral structure are very obscure; whilst in other portions of the same tube, they can be easily distinguished. In these it appears as if the spiral fibre had been broken up into small fragments, and that these had served as centres round which new deposites had accumulated; so that they had grown irregularly together, leaving interspaces in which the membrane is uncovered (as in the dotted duct) by this secondary wall. In fact it often happens that a duct, which exhibits in one part distinct remains of the spiral structure, approaches the character of the dotted duct so closely in another part, that they can scarcely be distinguished; and it is probable that the interior deposite which gives to the latter its peculiar character, may have originally taken place around the fragments of a spiral fibre.

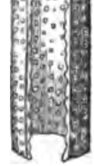

FIG. 30. SECTION OF A LARGE DOTTED DUCT, showing that the dots are thinner spaces of its walls.

85. In other instances, however, it seems clear that the ducts have originated in cells, which have lain end to end, and have been made to communicate with each other, by the breaking-down of the partitions between them; for the remains of these partitions may be not unfrequently detected. Sometimes these ducts remain, like the cells from which they

originated, of a simply membranous character; but more commonly, their walls are fortified by an interior deposite, which does not, however, entirely line them, but leaves the membrane bare at certain points, giving that dotted appearance already described in treating of the cells (§. 74). Hence these vessels are commonly termed *dotted ducts*. It is through such as these, that the sap principally rises in the stem and branches, and is conveyed to the leaves. They are by far the largest vessels contained in the vegetable fabric; and their open mouths are visible in almost any stem, when cut across. They are of particularly great diameter, when the stem itself is small and long, but bears a considerable amount of leaves, as is the case in the Vine and the common Cane; in these, their orifices at once strike the eye; and, if the stem of a growing plant be cut across, the oozing of the sap from their mouths will be easily distinguished.

86. The office of all these ducts is the same,—that of conveying fluid. It is only in the true spiral vessel, that we find air. These varieties have been described with somewhat greater minuteness than may appear necessary; because the young observer who examines the vegetable structure for himself, as it is hoped that many will be led by these pages to do, will be liable to be perplexed by meeting with them, if not previously acquainted with their characters.

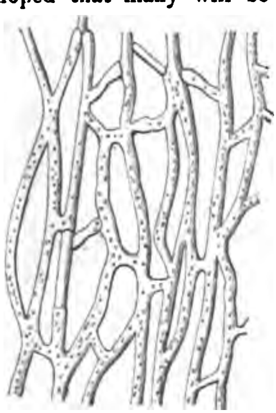

FIG. 31. — SYSTEM OF BRANCHING VESSELS, FOR THE CONVEYANCE OF THE LATEX OR NUTRITIOUS JUICE.

87. One other form of elementary tissue now remains; and this differs from all the rest. It is a system of *branching* vessels, confined to the under side of leaves, and to the bark, and serving only for the conveyance of the nutritious sap; which is carried by it from the leaves, where it is produced, down the bark, and thence to all parts of the structure. The walls of these branching vessels are extremely delicate, so that they can

be scarcely separated from the tissue around; hence it was long supposed that the nutritious sap, or *proper juice* as it is generally termed, flowed in mere spaces amongst other tissues, and not in distinct tubes. The existence of these, however, is now well established; and there can be little doubt that, like the straight ducts, they take their origin from cells, the partitions between which are broken down, so as to form a complete network of canals.

88. In future chapters, the combinations of these tissues in the several organs, such as the Stem, the Leaves, the Flowers, &c. will be described; but it may be well here to speak of one peculiar modification of cellular tissue which is seen in all these parts,—that, namely, which forms the *cuticle* or skin in which they are enveloped. The existence of this is easily shown in many leaves without preparation. From the leaf of the common garden Iris, for example, it may be easily stripped, or from the under side of that of the London Pride; and from every leaf it may be easily removed, after being soaked for a few days in water. This cuticle is found to be usually transparent and nearly colourless. If when separated it should appear coloured, this is due to the adhesion to it of some of the cellules of the fleshy portion (or *parenchyma*) of the leaf; these will afford an opportunity of examining the form and structure of these cellules; and they may then be wiped away, leaving the membrane perfectly smooth and colourless on both sides. Now when this is examined with a sufficient magnifying power, it is seen to consist of a number of flattened cells in close contact with each other; and these cells contain either air, or a colourless fluid. Their form is very different according to the kind of plant examined. Sometimes they are of a regular oblong and their sides straight; whilst in other instances they are of very irregular form, and lock into one another like the pieces of a dissected map.

89. Though the cuticle usually consists but of *one* layer of cells, it sometimes contains *two* or even *three*, especially in plants naturally growing in warm climates; and in the Oleander *four* may sometimes be distinguished. Its office appears to be, to prevent the moisture of the soft succulent tissues beneath from

evaporating; since, if they were to dry up, their vital properties would be lost. Accordingly we find it absent in plants which habitually live beneath the surface of the water, and from those parts of others which are usually submerged; whilst it is present on those parts of the same plants, which are lifted into the air; as well as on all the soft parts of those, which are habitually and entirely exposed to it. Its use is at once seen, when a portion of a plant destitute of it is exposed to the air;—it then speedily dries up and withers. On the other hand, the Oleander, exposed to the intense sunshine of tropical Africa, maintains its verdure, even in arid situations, by the great resistance to evaporation, which its thick and almost leathery cuticle interposes. The best mode of separating this cuticle, so as to become acquainted with its remarkable firmness, is to soak a leaf for a few days, in water rendered sour to the taste by a few drops of nitric acid; and it may then be easily stripped off. But its different layers can only be seen by magnifying a very thin slice of the leaf cut across; so that its thickness, not its surface, is exposed to view.

90. The whole of the softer portions of all plants growing in air is covered by cuticle; and in the young plant the entire surface. It is only when the stem increases in diameter, and the bark becomes hard and rugged, and occasionally scales off, that the cuticle can no longer be distinguished. It is evident on young shoots as on the leaves, and may be traced downwards to the point of the root; but *this* it does not cover. It also protects all the organs of which the flower is composed; but it is absent at one point, for reasons hereafter to be stated (Chap. XII.) The walls of the cells of the cuticle are often of considerable thickness, giving firmness to the organ it covers: such is evident in the leaves of the Holly, the hardened edges of which are composed of cells continuous with those of the cuticle.

91. The tissues protected by the cuticle are not entirely cut off by it, however, from the external air; for it has certain apertures of a very peculiar character, which open or close under the influence of light. These apertures are called *Stomata* (mouths). They are usually of an oval form, and bounded by two kidney-shaped cells containing green matter; and it is by the expansion

or contraction of these, that the orifice is diminished or increased. Sometimes, however, the opening is round, and is bounded by a ring of four or five such cells; and in the very curious stomata of the *Marchantia polymorpha*, one of the commonest of the Liverwort tribe (§. 32), there are five such rings, one beneath the other, the aperture resembling a funnel, and the lowest ring being the one, which regulates the amount of communication, between the chamber into which it opens, and the external air.

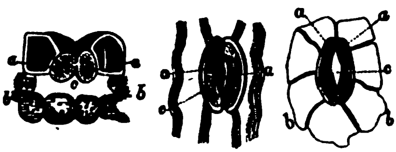

FIG. 32.—VIEWS OF STOMATA.—A, vertical section of stoma of Iris; *a*, *a*, green cells bounding the orifice; *b*, *b*, cells of the parenchyma; *c*, air chamber. B, view of the same from above; *a*, *a*, green cells of the stoma, lying between long cells of the cuticle; *c*, opening between them. C, similar view of a stoma of apple leaf; *a*, cells of the stoma; *b*, *b*, cells of the cuticle; *c*, opening of stoma.

92. Stomata are always placed over interspaces in the tissue, which are called *intercellular passages;* they are never found on the midrib or veins of a leaf, nor in fact over any hard woody portion of the structure. They are chiefly disposed over the soft green tissue of leaves and young shoots; but they are found also on the parts of the flower. When the leaves are absent, and the stem performs their functions,—as in the Cactus or Prickly-pear tribe,—stomata are found on its surface. They are generally most abundant on the *under* surface of leaves, and are sometimes altogether absent from the upper. This is partly due to the fact, that the tissne lying beneath the upper surface of leaves is so closely packed together, that there are scarcely any intercellular passages, into which the stomata might open; whilst the tissue in contact with the lower cuticle is extremely loose in comparison, and abounds with such passages; hence it is, that the colour of the upper surface of the leaf is usually so much deeper, than that of the lower. But in leaves of which the two sides are equally exposed to the air and light, such as those of the Iris, and of the common Flags growing by the sides of brooks, the general struc-

ture is nearly the same on the two sides, and the stomata are equal in number. Again in Plants, the circumstances of whose growth are such, that the atmosphere commonly comes in contact with the upper side only of the leaf,—as in the case of the Water Lily, the leaves of which float on the surface of the water,—the stomata are disposed on that side alone.

93. As there is no cuticle to protect the tissues of plants growing altogether beneath the surface, so there is no occasion for stomata to admit the passage of air to these; and accordingly in the whole tribe of Sea-weeds we find no vestige of them. Neither can they be distinctly traced in the Mushroom tribe, nor in Lichens; but in the Liverworts they present themselves, in the most remarkably complex form which we anywhere witness; in the Mosses they have only been detected on the stalk which bears the fructification; whilst in most Ferns, as well as in Flowering Plants, they abound.

94. Of the very minute size of these curious organs, some idea may be formed from the fact, that in some leaves it is estimated that 70,000 occur in a square inch of cuticle. The largest known are about the 1-500 of an inch in length; whilst the smallest are not 1-3000. Their function is evidently to allow of that limited evaporation of water from the soft tissues of the plant, which will hereafter be shown to be one of the most important of the processes, by which the crude fluid absorbed by the roots is converted into the nutritious sap or proper juice. The influence of light upon the stomata causes them to open, whilst they contract and even close in darkness.

95. It has also been shown, that light has a most important influence on their first production. In the young plant of the Marchantia (§. 33), when first separated as a kind of bud from its parent, no stomata or roots exist. It has been ascertained by repeated experiments, that stomata and roots may be caused to develop themselves in either of the two sides; the stomata being always formed on the upper surface, under the influence of light, and the root-fibres proceeding from the lower towards darkness. But if the surfaces be reversed *after* the respective organs have been developed to a certain point, so that the stomata

be directed towards the ground, and the roots be made to rise into the air, the little plant will right itself, by twisting itself round, so as to bring its surfaces to their former position. Further, when plants of a higher description are grown in darkness, the stomata are developed very imperfectly, or not at all. Thus we have an example of the very important effects of the stimulus of *light* upon the vegetable structure, not only in governing its actions, but in influencing its development.

96. With the cuticle may be advantageously considered those appendages, which are developed from it, as *hairs*, *prickles*, *stings*, &c. The leaves and stems of many plants are covered with hairs, which is sometimes bristly, sometimes soft and downy, and sometimes scattered very thinly. The structure of these hairs is various. Sometimes each forms but one long cell; whilst in many other instances, every hair consists of a row of cells placed end to end, and sometimes these send off minute side branches. The analogy of these cells with those of the cuticle, is shown by the curious fact, that many plants are hairy, or not, according to the circumstances in which they grow. Thus, when they are found in dry exposed situations, their stems stunted in growth, and their leaves

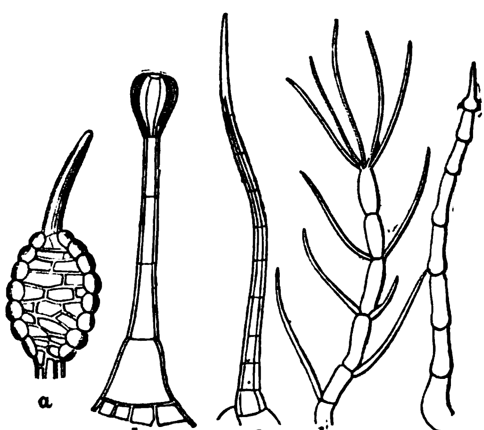

FIG. 33.—HAIRS AND GLANDS OF VARIOUS KINDS; *a*, gland surmounted by a hair; *b*, small gland at the top of a hair; *c* and *e*, simple hairs; *d*, branching hair.

small, their surface is covered with hairs, as if the cells which

would have otherwise formed a larger cuticle had taken the shape of hairs: whilst in damp shady places, which favour the extension of the leaves and stems, their surface is quite smooth, all the material being then required to form cuticle. It will be shown hereafter (§. 278) that the development of hairs on the surface of the leaves of plants growing in dry situations, favours the absorption of moisture.

97. Sometimes the hairs are tubular and pointed, and are fixed upon minute glands in the cuticle, which secrete an acrid fluid; and if but very slightly touched, the reservoir at the base is compressed, and the fluid forced up through the tube, into the wound made by its pointed extremity. Such hairs are termed *stings;* and the Nettle affords a familiar example of them.—The *prickles* of the Rose and other shrubs are also appendages of the cuticle, with which they are stripped off, and from which it is easy to detach them. They are thus distinguished from *thorns*, which proceed from the wood of the branch, and which, as will be hereafter stated, may be regarded as stunted leaf-buds. Prickles, after being once formed, and hardened by the process already described (§. 74), undergo no subsequent enlargement; and, accordingly, if the cuticle on which they are fixed should be extended, their base is not able to expand in the same proportion, and they drop off, leaving scars on the surface of the stalk.

98. Another interesting modification of cellular tissue, is that which surrounds the spaces or cavities, formed in certain plants for special purposes. Thus in the Duckweed, the leaves are provided with a set of air-chambers, which give them great buoyancy; and nothing can be more beautiful than the manner in which the walls of these chambers are built up of *muriform* cellular tissue.—In other cases, these cavities appear to be formed as receptacles for certain secreted products: and here, too, they

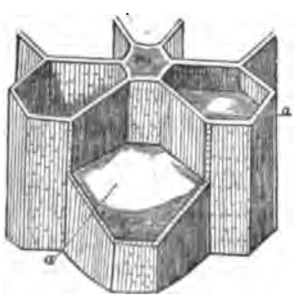

FIG. 34.—AIR-CHAMBERS OF AN AQUATIC PLANT, THE VERTICAL WALLS FORMED OF MURIFORM CELLULAR TISSUE.
a, a, horizontal partitions.

are very beautifully partitioned off from the surrounding tissue, by a peculiar disposition of the cells. A good illustration of these, is found in the rind of the orange and lemon; the odour and flavour of which, are derived from the minute drops of volatile oil, stored up in a vast number of these little cavities. The turpentine of resinous woods is collected in large channels of the same description.

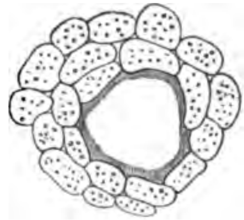

FIG. 35.—RECEPTACLE FOR FLUID SECRETION; A CAVITY BOUNDED BY CELLULAR TISSUE.

99. It is scarcely possible to observe the number of different forms (of which many have been left unnoticed) resulting from the varied combinations of the simple elements—*membrane* and *fibre*,—each of them probably having its peculiar function in the Vegetable economy, without being struck with the simplicity of the plan, by which Creative Design has effected so many marvels, as well as with the extreme beauty and regularity of the structures, which are thus produced. The comparison of such specimens of Nature's workmanship, as the meanest Plant affords, with the most elaborate results of human skill and ingenuity, serves only to put to shame the boasted superiority of Man; for whilst every additional power which is applied to magnify the latter, serves but to exaggerate their defects, and to display new imperfections, the application of such to organized tissues, has only the effect of disclosing new beauties, and of bringing to light the concealed intricacies of their structure.

We shall next pass on to consider the structure of the *compound organs* of the Vegetable fabric, and their several purposes and uses.

CHAPTER IV.

STRUCTURE AND FUNCTIONS OF THE ROOTS.

100. The *Roots* are the parts of the plant, on which it is chiefly dependent for the supply of the moisture, which its growth requires; and they also serve to fix it in the earth. That they absorb or suck up fluid with great rapidity, may be easily shown in the following manner. Take any small plant that is growing in the soil, and immerse its roots (first clearing them of earth) in a tumbler of water. If the plant be exposed to the light of day, and especially if the sun shine brightly upon it, the water will disappear very much faster from the glass, than from one exposing the same surface, and placed in the same circumstances, but without the plant. And if the specimen continue to grow and flourish, it will take up many times its own weight of water in a short period. Thus, four plants of Spearmint, grown during 56 days with their roots in water, and themselves weighing all together but 403 grains, have been observed to take up 54,000 grains, or about seven pints of the fluid.

101. Of the water thus absorbed, a small proportion only is retained within the plant, serving as a part of its food. The greatest part of it is sent off again from the leaves, by a process hereafter to be described (Chap. VIII.), termed Exhalation; and the rapidity of Absorption is in part governed by the rapidity of Exhalation. The latter is nearly checked by the absence of light; and, accordingly, plants are found to absorb but little in the night, or in a dark room. Any of the causes, which will be subsequently stated to influence the latter, affect the former in a nearly corresponding proportion. The object of the introduction of a quantity of fluid into the vegetable system, so much larger

than it retains, appears to be this;—the solid mineral matters, which constitute an important part of the food of the plant, are contained in the water which reaches its roots, in excessively minute proportion; and it is therefore necessary, in order that a sufficient amount of these may be obtained, that all the water in which they are dissolved should be introduced. As this is by far too much for the other wants of the plant, a large part of it is got rid of by Exhalation.

102. It is only in the more perfect plants, however, that we find a restriction of this power of absorption, to one particular portion of the structure. In the Sea-weeds, for example, the whole surface appears equally endowed with this faculty; and there is, therefore, no occasion for that transmission of fluid from one part to another, which is characteristic of those, in which we find a stem (or something correspondent with it), bearing roots at one end, and leaves at the other. Accordingly, that which is the natural condition of the latter, is fatal to the stemless plants; for if a Sea-weed be suspended partly out of the water, the upper portion will die from drought, whilst that which remains immersed will continue to live and grow, without transmitting any of its moisture to the rest. (See §. 41.)

103. In some of the Cryptogamia a little higher in the scale, however, we find a condition much more approaching that of the Flowering-Plants. Thus, in the Mushroom, we observe a soft stem, which sends off fibres into the ground; and these appear to absorb by their whole surface, and to transmit the fluid they have acquired, to the portion which is elevated in the air. In the Mosses, the tissue of the stem is firmer, and the rootlets which proceed from it are more woody; these not only project from the stem, but also from the under surface of the leaves; and thus the dryness of the situations, in which these interesting little plants find their subsistence, is in some degree compensated for. In Ferns we have a woody stem and widely ramifying roots, like those of the Phanerogamia.

104. If we examine the roots of any common plant with a branching woody stem, such as the Rose, we shall find that they subdivide and spread beneath the ground, very much upon the

same plan with the branches above. Moreover, it will be seen that, from the sides and extremities of these underground branches, there proceed a number of delicate fibres; and if the extremities of these be carefully examined, they will be found to be much softer than the rest of the structure. Now these fibrils are the true roots; and their soft succulent extremities, which are called *spongioles*, are the parts by which alone they absorb or suck up fluid. This is easily proved. If a growing Radish be carefully removed from the ground, and the fleshy portion be bent in such a manner, that it can be covered with water, whilst the leaves and the tuft of fibres at the point of the root are not immersed, it will be found that the whole of this large surface does not absorb moisture enough, to keep the plant alive. But, on the other hand, if this tuft of fibres be only so far immersed in the water, that their points may touch it, whilst the rest of the root is above the surface, the plant will continue to flourish.

105. The fact is, that this absorption takes place with the greatest rapidity, through soft newly-forming tissue; and this is what gives the spongioles their peculiar power. They are, indeed, simply the *growing points* of the rootlets, which are constantly increasing in length, and which in this manner go in search, as it were, of the supplies of food, of which they have exhausted the soil that previously covered their extremities. As this growth continues, the tissue at first formed gradually becomes consolidated; and when it has become hardened, it is no longer adapted for absorption in more than a very trifling degree; so that, to the newly-forming point of the fibre, this power is always nearly restricted. But in the young plant, there is an interesting correspondence with the condition of the lower tribes; for the soft roots, which are first sent down from the seed, when it is commencing to grow or germinate, are, like the fibres proceeding from the base of the Mushroom-stem, capable of absorbing by their whole surface; and it is only when woody fibre begins to be formed in them, that the power is restricted to their extremities.

106. The knowledge that the delicate fibres, proceeding from what are commonly known as roots, are the true and only organs

of Absorption, has an important practical application. It very commonly happens that, in *transplanting* shrubs or trees, of which the roots extend a good way into the soil, enough care is not taken to preserve these; and the plant either languishes for some time, until it is able to form new ones, or dies altogether. It is seldom that, under common treatment, a fruit-tree will bear in the first season after transplantation. The following instance, however, will show what mode of proceeding is directed by the knowledge just communicated, and what success attends it. A gentleman in Shropshire had some valuable vines, which he wished to remove to a new property on which he was going to live in Norfolk. He had a trench dug around them, at such a distance as, it was believed, would include all their roots. The earth within this was then removed, not with spades and trowels, but with the fingers,—every fibril being thus uncovered without injury. The mass of roots was then wrapt in moist matting; the vines were carried across England, and then planted; and in the ensuing season they bore an abundant crop.

107. It is often observed, that the growth of roots takes place, in the direction best adapted to supply them with moisture; and it has been supposed that plants possessed a kind of instinct, or consciousness, which caused them to select this. Many of these cases, however, can be explained without having recourse to such a supposition; and it is probable that, with the advance of knowledge on this subject, the remainder will be also. In fact, to attribute such an instinct to Plants, is to place them above the lower Animals, which do not exhibit the power of making a choice of this kind. The most common cases are those most easily explained. A plant is in a dry soil, and it sends out its roots into a moister one; or it is in a garden-pot, and its roots project through the hole at the bottom, into the water which the pan below it may contain, or into the moist earth with which it may be surrounded. Now this is explained upon the following simple principle. The addition which is constantly being made to the extremities of the fibres, takes place in the direction of *least resistance;* and, when the roots are making their way through a hard dry soil, the direction of least resistance will be

that, in which the earth is loosened by the flow of water; towards the source of that moisture, therefore, the growth of the roots will be directed.

108. The same principle has another curious application. Roots have been known to insinuate themselves into the crevices of walls, or even into chinks in the stones themselves; and to burst asunder the walls of these after some time. Now when a root meets with such an obstacle as this in its growth, it is turned aside for a time, and endeavours, as it were, to creep round it. But should a chink give the opportunity for the new tissue to be deposited without obstacle, in its original direction, the root will find its way into it. The fibril will grow, by the nourishment sent to it, and by its own absorption, until it can no longer increase, without the separation of the walls which confine it; and this is accomplished by the force with which it imbibes fluid, which causes it to distend itself with great violence.* This distention is of the same character as that of a piece of dry wood, when exposed to moisture.

109. The foregoing explanations will apply to a case of no unfrequent occurrence, in which a tree growing on one side of a road sends out roots to a ditch or stream on the other,—these roots dipping deep beneath the hard bed of the road, and rising again on the farther side. It is evidently by the slight drainage or percolation of water, which will take place along this line, that the roots follow the same course. A more remarkable case, however, which has been more than once observed, is where the roots direct themselves along a naked rock, to reach water at a distance of perhaps twenty feet: or where, as in a case recently seen by the Author, a tree growing near the side of a well, has sent down a root through a narrow chink in its side; which root, after descending for several feet without subdivision, has thrown out a vast number of small branches and fibres, as soon as it

* It is by this same kind of force, resulting from *Capillary Attraction*. (see MECHAN. PHILOS. §. 30) that mill-stones are split in quarries. A long cylinder is first cut out; and grooves are then chiselled in its circumference, at the points where it is desired to divide it. Wedges of wood are then driven into the grooves, and these are moistened; by their violent expansion, the stone is split into the required number of parts.

approached the surface of the water. It is not improbable that the constant ascent of vapour into the air in that direction, may be in part the cause of this curious mode of growth. An instance occurs in Leigh Woods near Bristol, which remarkably illustrates this tendency of roots, to grow towards the spot most fitted to afford them nutriment. In a little hollow on the top of the shell of an old Oak (the outer layers of which, however, and the branches, are still vegetating) the seed of a Wild Service-tree was accidentally sown. It grew there for some time, supported, as it would appear, in the mould formed by the decay of the trunk on which it had sprouted; but this being insufficient, it has sent down a large bundle of roots to the ground, within the shell of the Oak. These roots have now increased so much in size, that, as they do not subdivide until they nearly reach the ground, they look like so many small trunks. In the soil, however, towards which they directed themselves, there was a large stone,—about a foot square; and, had their direction remained unchanged, they would have grown down upon this. But about half a yard above the ground, they divide, part going to one side, and part to the other; and one of them branches into a fork, of which one leg accompanies one bundle, and one the other; so that, on reaching the ground, they enclose the stone between them, and penetrate on the two sides of it.

110. This example serves to show another fact,—that it is not, in every case, that we are to regard the parts of the axis which are above ground, as Stems, and those which are beneath it, as Roots. There is a tree peculiar to tropical climates, called the *Pandanus* or Screw Pine, in which the roots are always formed in somewhat of this manner. The stem is smallest at its lowest part, and it enlarges considerably above; hence it would be very unsteady, without some additional support; and this is provided for, by the transmission of the roots, not only from the bottom of the stem, but at different parts of its ascent. These grow downwards in the air, and are provided at their extremities with a kind of cup, which catches the rain and dew by which they are partly assisted in their elongation; when, however, they have reached the ground, this falls off, and their

extremities become true spongioles. When they begin to absorb

FIG. 36.—PANDANUS OR SCREW PINE. *a, b, c,* aerial roots partly serving as stems; *d, e,* roots not yet reaching the ground.

nourishment from the earth, they increase greatly in diameter, and seem like so many assistant-stems.

111. The general fact is, that the Root is the portion of the axis, which has a tendency to grow downwards towards moisture, and away from light; whilst the Stem is the portion, which tends to grow upwards, into the dry air, and towards light. This tendency is manifested, during the earliest period of the growth of a plant from seed. Two parts always originate from it; one of which, termed the *plumula* (from its resemblance, when just unfolding, to a little feather), is the rudiment of the stem and leaves; whilst the other, called the *radicle*, is the young root. The first of these exhibits from the commencement a tendency to grow upwards, and the second a similar tendency to descend. The late ingenious experimenter, Mr. Knight, devised a means of showing, that the direction of the roots is in part owing to the

force of gravity. He placed some germinating beans on the circumference of a vertical wheel; and made this revolve rapidly and continuously for several days. From the constantly varying position of the seed, the force of gravity was here neutralised; but a new force was substituted for it,—the centrifugal force, or tendency to fly from the centre, which a stone (for example) let loose from the circumference of such a wheel whilst revolving would exhibit.* The root, influenced by this force as ordinarily by that of gravity, grew, in every instance, away from the centre of the wheel, whilst the stem grew towards it.

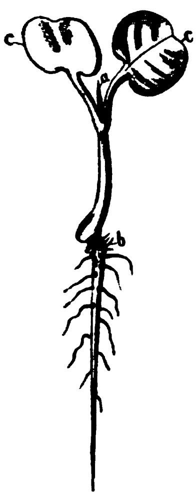

FIG. 37.—GERMINATING SEED.
a, plumula; *b*, radicle.

112. In another experiment, the wheel was made to revolve horizontally, so that the force of gravity continued to operate, but in combination with the centrifugal force; in this instance, the direction of the radicle showed the evident influence of both; for it pointed downwards and outwards. *Why* the radicle should be thus influenced by the force of gravity, when the plumula grows in opposition to it, is a question that has not yet been answered; but it is interesting to know the fact. We are as completely ignorant of the ultimate causes of the most common occurrences. We do not know, for example, *why* the earth should attract the bodies on its surface, or why it should itself be attracted by the sun. We only know the general fact, that all masses of matter attract one another.

113. Roots are ordinarily distinguished from stems, not only by their direction, but also by the presence of the absorbing fibres, and by the absence of buds,—which last are so characteristic of the Stem, that any part on which they appear may be ordinarily considered such, even though it is growing underground. In general, however, the stem possesses the power of sending out

* See MECHAN. PHILOS. §. 211.

root-fibres from any part; as is shown, by breaking off a slip of a branch and sticking it in the ground; when if properly attended to, it will usually form roots for itself, and soon become a new plant. But it is more rare to find the roots capable of forming leaves and flowers; this, however, is the case in some instances, such as the Maple—a tree which may be completely inverted, the branches being buried in the ground, and the roots spread forth into the air, without being destroyed.

114. The structure of the root-fibre, and of the spongiole which terminates it, may be beautifully seen in the common Duckweed; in which a single such fibre hangs from the under surface of every leaf, for whose nourishment it is destined. On looking at it with a magnifying-glass, or microscope, a dark line is seen along its centre; this consists of the bundle of vessels, by which that part is occupied. These are enclosed in a firm sheath of cellular tissue; and at the point, this tissue is observed to be softer, more spongy, and less regularly formed. The extremities of the fibres are often seen to be covered with a little cap, that corresponds with the cup which the aerial roots of the Pandanus have been spoken of as possessing (§. 110).

115. The wide-spreading roots of a forest-tree do in reality consist but of bundles or collections of such fibres, strengthened by woody structure resembling that of the stem, and arranged in the same manner. The structure of the woody roots corresponds mainly with that of the stem; being Exogenous in Exogens, and Endogenous in Endogens (Chap. v.); but in the former no pith exists in the roots, their centre being occupied by vessels. The spread of the roots from the stem, is usually greater than that of the branches; so that the rain which is prevented by the latter from falling direct upon the ground, is directed just to that part through which the root-fibres are distributed, ready to suck it up.

116. The force with which the roots absorb fluid is very considerable. If a Vine be wounded in the stem, when the sap is rising in the spring, a large quantity will flow out, and will continue to do so for some time. An Elm tree, from which a portion of the bark and outer layers of wood had been accident-

ally torn off, has been known to pour forth from the wound many gallons in a few hours; and the loss could only be restrained, by nailing a leaden plate very firmly over the part. If the stem of a Vine be cut through, when the sap is ascending, and a piece of bladder be tied over the surface of the lower part, this is soon distended with fluid, and in a few hours will burst. Or if to this portion be fixed a bent tube, in such a manner that the fluid which rises shall have to lift a column of mercury, the absolute force may be measured; and this is found to be very great.

117. The question, then, arises,—by what power do the roots thus absorb and force upwards through the stem the fluid of the surrounding soil? Is this power peculiar to the living system, or can we in any way account for it on the laws of Mechanics? Something analogous may be effected by the experimenter, with materials which he obtains from dead structures, or even from inorganic matter. If a glass vessel, of the shape delineated in the figure, have its wide open mouth covered with a piece of bladder, and its cavity filled with rather thick syrup or gum-water, whilst the under side of the bladder is immersed in simple water, the volume of fluid within the glass will be much increased, by the passage of water from without, through the bladder, to mix with the fluid in the interior; and this entrance will continue, as long as there is much difference in density, between the fluids on the two sides of the bladder. But there is also a contrary current to a less amount,—the interior fluid passing out to mix with the surrounding water. The increase in the volume of the fluid within the vessel is, therefore, equivalent to the difference in the amount of the opposite currents. If, on the other hand, the glass were filled with water, and immersed in syrup, it would be partly emptied by this action.

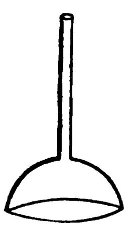

Fig. 32.

118. The principal current is termed *Endosmose* (flow inwards); and the lesser one is called *Exosmose* (flow outwards). Bladder or animal membrane is by no means the only porous substance, which may be used for this purpose; though it is the most fitted to exhibit the experiment, from the rapidity of the

action which takes place through it. Half-baked porcelain, and a peculiar porous limestone, have been shown to have the same properties; so that it is evident, that this curious result is not dependent upon any modification of *vital* power. It is, in fact, but a peculiar form of *capillary attraction.**

119. Now the conditions requisite for this action, are two fluids of different densities, separated by a *septum* or partition of a porous character. This we find in the roots. The fluid in their interior is rendered denser than the water around, by an admixture (as will be hereafter explained, §. 140) of the descending sap; and the spongiole supplies the place of the partition. Thus, then, as long as this difference of density is maintained, the absorption of fluid may continue. But if the rise of the sap is due to the action of Endosmose, there ought also to be an Exosmose. This is found to take place; for if a plant be grown with the roots in water, the fluid surrounding them is soon found to contain some of the peculiar substances they form, and which are contained in the descending sap; thus a Pea or Bean would disengage a gummy matter,—a Poppy would communicate to the water an opiate impregnation,—and a Spurge would give it an acrid taste.

120. Thus we see how beautifully and how simply this action, extraordinary as it seems, is accounted for, when its whole history is known, on principles which operate in other departments of Nature. It has been asked,—why should not Endosmose take place, when the roots of a dead plant are put in water? This question may be answered by another;—why does the wick of a lamp suck up oil, only when it is lighted? The answer to both is, that it is only when the fluid already absorbed is in some way removed, that absorption can go on. In the latter case, as fast as it is withdrawn by combustion, the lower part of the wick raises it by capillary attraction. In the former, as fast as the fluid is got rid of by exhalation from the leaves (Chap. VIII.), the Endosmose below will keep up the supply; but if the demand is suddenly checked, (as when the plant is withdrawn from the influence of light, or its vitality be

* See MECHANICAL PHILOSOPHY, §. 28.

destroyed by an electric shock,) there is no room for any additional fluid within the system, and the absorption is checked also.

121. When the upper part of the stem is cut off, the sap will continue to rise by the force of Endosmose in the roots, so long as the fluid *within* is of greater density than the fluid *without*. But that will soon cease to be the case, the actions of the leaves being destroyed, and no descending sap being intermixed to keep up the force. These two causes, then,—the absence of any demand for sap in the leaves, and the cessation of the condition necessary for the maintenance of Endosmose,—are quite sufficient to account for its absence in the dead plant; and its performance soon becomes impossible for another reason,—the decay of the soft tissue of the spongiole, through which it is performed.

122. The nature of the fluid absorbed by the roots of plants will be more fully discussed in Chapter VI.; when their food, and the mode in which they are nourished by it, will be described. It may, however, be stated here, that they appear to have a certain power of *selection*,—some of the substances dissolved in the fluid which surrounds the roots being absorbed, and others being rejected. Thus, if a grain of Wheat, and a Pea, be grown in the same soil, the former will obtain for itself all the *silex* or flinty matter, which the water can dissolve; and it is the deposition of this in the stem, which gives to all the Grasses so much firmness.* On the other hand the Pea will reject this, and will take up whatever *calcareous* substances (or those formed of lime and its compounds) the water of the soil contains,—these being rejected by the Wheat.—Again, if the roots be placed in water, coloured by any substance, of which the particles are very minute, the finest of these will be absorbed with the fluid, and will be carried to the leaves; whilst the coarser ones are left behind. In the same manner, if the roots be immersed in a solution of gum or sugar, a certain proportion only of these substances will be taken up with the fluid in which they are dissolved; and that which remains will thus become gradually thicker.

* There is enough silex in a Wheat-straw to make a bead of glass, when melted with potash with the blow-pipe; and in the Bamboo it is sometimes collected in the knots in large masses, forming the substance called *tabasheer* in the East. See also §. 201.

CHAPTER V.

OF THE STRUCTURE AND FUNCTIONS OF THE STEM.

123. THE chief office of the Stem appears to be, to elevate the leaves—which are organs destined to convert the crude fluid absorbed by the roots, into nutritious sap for the supply of food to the structure,—and the flowers,—in which a part of this sap is applied to the production of new individuals,—into the most favourable position for receiving the influence of light, heat, and air, on which their due actions depend. Accordingly we usually find it most developed, in those kinds of plants, in which one portion of the surface is set apart for the absorption of fluid, and another for its exposure to these influences. In the little plant which constitutes the Red Snow, and in others of a similar grade of organisation, we find the whole surface adapted to absorb, and the whole surface equally exposed to air; there is, therefore, no necessity for a stem. But as soon as, in the Mushroom tribe for example, the plant sends roots into the earth, it elevates the other portion above it by means of a stem; and in this stem there is a set of channels or passages, which serve to convey the absorbed fluid from below upwards. But in these humble plants, destined to live but for a short time, and then speedily to decay, there is no necessity for providing the short stem with the toughness required in the trunk of the lofty forest-tree, which braves the storms of centuries. And accordingly we find that, whilst in the former the tissue is soft and cellular, resembling that of the rest of the structure, in the latter it is firm, consisting almost entirely of woody fibre; and that this is consolidated, by the deposition of hard matter within its tubes.

124. Between these two extremes of softness and toughness,

there are a great many intermediate conditions. In flowering-plants which only live for one year, and are hence known as *annuals*, the stem is usually *herbaceous*;—that is, it consists almost entirely of soft cellular tissue, but contains, however, some bundles of woody fibre and vessels, which may be traced to the stalks of the leaves. These are commonly known as the *strings* of vegetables whose stalks or roots are eaten, such as Asparagus or Turnips; and that degree of *stringiness* which makes such plants unfit for the table, when their growth is too far advanced, results from the increased formation of woody fibre, which takes place towards the end of the season. In those plants, however, the duration of whose life is greater, the stem gradually becomes consolidated by the formation, in each year, of a new set of these bundles; so that, in time, the soft cellular part bears but a small proportion to the whole. Herbaceous and woody stems, however, are at first formed upon the same plan; the structure of a first-year's branch of an Oak, for example, being essentially the same with that of the stem of an annual Pea. The foundation is laid, as it were, by an extension of the cellular tissue from which it springs at first, this being the kind of structure which most rapidly increases; and the consolidation of this is then gradually effected, by the deposition of woody fibre in its substance.

125. But the stems of Flowering-plants are not all formed upon the same plan; in fact there are two different and nearly opposite modes, in which the woody bundles are arranged in the stem; and to one of these, they may be all referred. If the stem of the Asparagus be cut across, it will be seen that they are distributed at intervals through its whole substance. On the other hand, in the stem of a Pea they would be seen regularly arranged in a circle, a little beneath the exterior. The former, if it continued to live and grow, would have its new bundles deposited in the *interior* of the stem; whilst the latter, if it survived a second summer, would have a new circle of woody bundles deposited on the *exterior* of the first. The former is then called an ENDOGEN, (growing from within); the latter an EXOGEN (growing outside). To the *first* division belong the Palms,

Bamboos, Canes, and many other hard-stemmed and lofty tribes, inhabiting tropical climates; but scarcely any except herbaceous

FIG. 39.—AGAVE AMERICANA;—ENDOGEN.

plants belonging to this division, exist in temperate regions; the chief tribes which it includes in this country being the Lilies, with most other bulbous-rooted plants, and the Grasses. To the *second* belong all the trees and shrubs, and a large proportion of the plants, of temperate climates; whilst between the tropics, its place is partly occupied by the other. The last, as being the best known in this country, will be first described.

126. If we cut across a young twig of any common tree or shrub, such as the Ash, Elder, &c. we shall observe that it consists of three distinct parts, ordinarily known as the *Pith*, *Wood*,

and *Bark*. The *pith* is a soft spongy substance occupying the centre; if a thin slice of it be cut, either across or vertically, and magnified, it is seen to consist entirely of cellular tissue, the cells

FIG. 40.—BEECH TREE :—EXOGEN.

of which are mostly of a very regular form (§. 71). When young it contains a good deal of fluid, and has a greenish hue; when the branch is older, it becomes white and dry; and in an old stem or branch, it is often found to have shrivelled up and almost entirely disappeared.

127. Now this pith is the first-formed portion of the Stem; being in fact the remainder of that cellular structure, of which the whole was originally composed, but which gradually gives

place to the woody portion: and whilst at first it has to impart nourishment to the organs which are growing from it, this function is performed more perfectly by the vessels, as soon as they are developed in the stem, and the pith becomes of no further use. The pith of a branch is always an extension of that of the branch or stem from which it sprang; and if the latter be cut through, just where a bud is rising from it, this will be seen at first to consist, almost entirely, of a kind of prolongation of the cellular portion, which occupies its centre. The pith of trees is applied to no important use. One curious product is obtained however from the large pith, which constitutes nearly the entire stem of an herbaceous plant; this is the substance known as *Rice Paper*, which is made by cutting the soft portion of the stem with a sharp knife, in a spiral manner, so as to cause it to spread out, as if a sheet of paper were being unrolled from a round ruler. It is then flattened out by pressure; but its character, as cellular tissue, like that of other piths, may be easily shown by magnifying a small portion of it.

128. The pith is surrounded by the *woody* layers, the number and thickness of which depend upon the age of the branch or stem. In the herbaceous stem, the woody portion (as already stated) presents itself in the form of distinct *strings*, arranged in a circle between the large pith and the external skin or bark. Each string is separated from its neighbours by a prolongation of the pith, which thus maintains its connection with the bark. In the stem of a second year, however, these bundles are found to form a second ring, enclosing the first, but still beneath the bark; which is carried outwards, as it were, to admit it. The prolongations of the pith still exist; but they become narrower in each ring, and at last appear merely

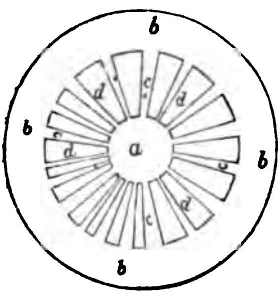

FIG. 41.—DIAGRAM ILLUSTRATING THE FORMATION OF THE STEM. *a*, pith; *b*, bark; *c, c, c*, plates of cellular tissue connecting them, termed medullary rays; *d, d, d*, woody bundles interposed between these.

as lines diverging from the centre. They are called *medullary rays* (or rays passing off from the *medulla* or pith); and their office is to maintain a constant connection, between the pith and interior of the stem, and the bark or exterior, for an important purpose hereafter to be mentioned (§. 140). The thin plates which they form, crossing as they do the direction of the fibres of the wood, are known as the *silver grain* by Carpenters. In many instances they add greatly to the beauty of the wood.

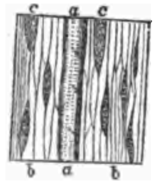

FIG. 42.—VERTICAL SECTION OF A PORTION OF AN EXOGENOUS STEM, IN A DIRECTION CROSSING THAT OF THE MEDULLARY RAYS: *a*, *a*, dotted duct; *b*, *b*, woody fibres; *c*, *c*, cut ends of the medullary rays.

129. The number of rings or layers, of which the wood of any stem or branch consists, is in general easily reckoned by cutting it across, as shown in the accompanying series of figures. They correspond exactly, in this climate, with the number of years which the part has existed. But there is reason to believe that, —though in temperate climates, the trees of which shed their leaves and renew them once a year, a layer is formed no oftener, —in tropical climates, where many kinds of trees have two or three successions of leaves in a year, a corresponding number of layers will be formed:—

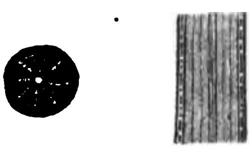

FIG. 43.—FIRST YEAR MAGNIFIED.

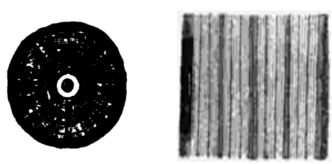

FIG. 44.—SECOND YEAR.

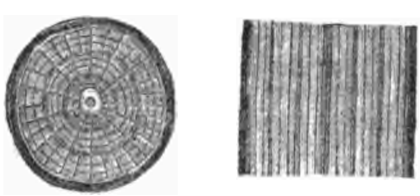

FIG. 45.—THIRD YEAR.

FIG 46.—TRANSVERSE AND PERPENDICULAR SECTIONS OF A STEM FOUR YEARS OLD; the latter through the pith. *a*, pith and wood of the first year; *b*, *c*, *d*, layers of wood of the second, third, and fourth years; *e*, the four thin layers of bark.

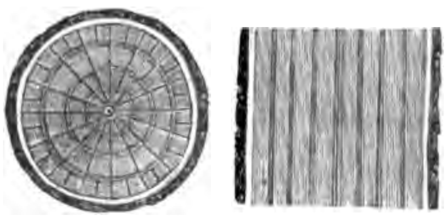

FIG. 47.—SECTIONS OF A STEM AS IT APPEARS IN MAY OR JUNE OF THE FIFTH YEAR. The white spaces show the swelling cambium.

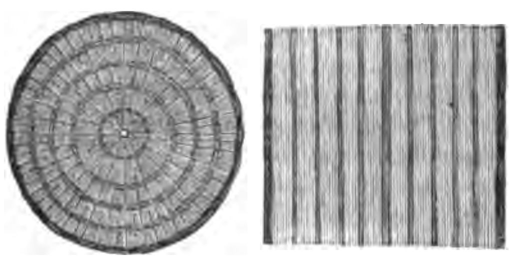

FIG. 48.—SECTIONS OF A STEM AT THE END OF THE FIFTH YEAR. The envelopes and layers of liber are too thin to be shown by the pencil.

In this way we can account for the extraordinary number of layers, in the Baobab trees of Senegal; without having recourse to the supposition, that they were above 5000 years old, as we must otherwise regard them.

130. Each layer of wood consists partly of vessels or ducts,

and partly of woody fibre. The former always lie next the centre, and are the parts earliest formed; the latter protects them on the outside, and is produced towards the end of the season. The mode in which these are arranged, however, varies in different trees; and it is principally this, which gives that beautiful variety, observed in sections of many woods, when examined with the microscope. The ducts are at once distinguished, by the large size of their orifices; and the woody fibres by their comparative minuteness. Amongst the ducts, however, we usually find lying some elongated cells, which fill up the spaces between them, and which sometimes resemble woody fibres in form, but differ in the firmness of their walls. Whatever be the number of annual layers, they are always traversed by the medullary rays, which continue to extend outwards, with every addition to the diameter of the stem, even when the pith and the inner layers of wood have decayed away.

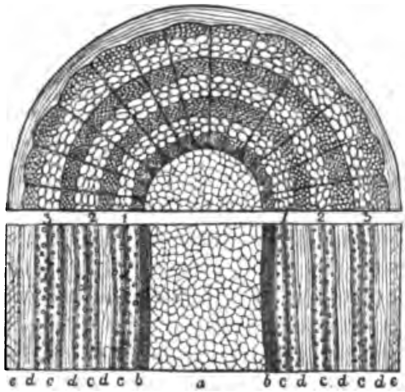

FIG. 49.—HORIZONTAL OR TRANSVERSE, AND PERPENDICULAR SECTION, OF THE STEM OF AN EXOGEN OF THREE YEARS' GROWTH. In the centre of each is seen the pith, *a*, composed of cellular tissue; surrounding it is the medullary sheath, *b*; and exterior to it are three rings of wood, each consisting of *c*, *c*, dotted ducts, and *d*, *d*, woody fibre. The last-formed is in contact with the bark, *e*, *e*, in which the layers are indistinct.

131. In most trees, of which the wood is used as timber, the inner and older portion is much harder and drier than the exterior. Sometimes there is an evident line of demarcation, between the *heart-wood*, or *duramen*, as it is called, and the *sap-wood*, or *alburnum;* this is seen, for example, in the lignum-vitæ, and coco-wood, which are much employed by turners. But in most cases, the change of character is more gradual. This change is due to the consolidation of the interior wood; by the depo-

sition in its tubes, of resinous and other matter, secreted by the plant. The portion of the stem in which this has taken place, thus acquires great toughness and durability, but it is no longer fit to perform any office in the living system, save that of mechanically supporting the rest; since no fluid can pass, in any way, through the now-filled-up channels. It is through the newer layers, or sap-wood, therefore, that the sap entirely ascends; and these, in their turn, become inclosed by others; and are at last consolidated, like the more aged ones, into duramen. The heart-wood alone is used by the artisan; for the sap-wood soon splits and decays.

132. As the pith and the inner layers thus gradually lose their original employment, and as in the outer part of the stem alone any active processes of vegetation go on, the former may be removed without injury to the latter; and this is often naturally accomplished by decay, which destroys the *heart* of an aged tree, with some portion of the exterior of the stem, but leaves the remainder a mere shell, still capable, however, of putting forth buds and branches, and of adding to its own thickness.

133. The chief important variety in the structure of the Exogenous stem is that exhibited in the Pine and Fir tribe. No ducts exist in their wood; whilst the diameter of the tubes of the wood itself is greater than in other cases; so that a horizontal section of the stem shows a series of openings of very nearly the same size, arranged with beautiful regularity, the division into annual layers being usually well-marked. As a general rule it may be stated, that these are separated by the most distinct line, in trees inhabiting temperate or cold climates, whose vegetating processes are entirely suspended by the cold after each layer is formed; whilst in trees of warmer regions, they pass into one another more gradually. In the former, too, there is often a considerable difference in the thickness of the respective layers, according as the seasons have been favourable, or otherwise, to the formation of wood; whilst in the latter, their thickness is in general nearly uniform.

134. These facts come to be of much interest, when we examine the structure of the fossil plants, which are not unfre-

quently found imbedded in solid rock; for they thus afford evidence, that the temperature of this quarter of the globe was both higher and more equable at the time they grew here, than it is at present;—an opinion which is equally supported, by the nature of the fossil remains of Animals existing at the same period.

135. Between the pith and the adjacent layer of wood, a delicate membrane may be traced, which is termed the *medullary sheath.* This consists almost entirely of spiral vessels, which are seldom found in any other part of an Exogenous stem, except when they pass off from this, towards the origins of the leaves. Their office is a very important one, as will be hereafter seen (§. 324).

136. The wood is inclosed by the *bark*, which is, like it, formed in regular layers; though these are much thinner, and cannot be so plainly distinguished. The layers of bark are formed from the *interior*, so that the oldest are on the outside. These are gradually lost, either by decay, or by falling off; so that it is very seldom, that the same number can be traced in the bark as in the wood, although an additional one is formed in each at the same time. As the new layer of wood is formed on the *outside* of the previous one (at the point, therefore, at which it is in contact with the bark),—and as the new layer of bark is added to the *inside* of the previous one (at the point, therefore, at which it was in contact with the wood),—it is obvious that they are produced at the same spot; and that the newest layers of both will always be in contact with each other. Their production seems to take place in somewhat of this manner. At the end of the spring, the bark becomes loosened from the wood, with which it was previously in close contact, and a glutinous fluid, termed the *cambium*, is found between them (see Fig. 47). This may be observed, by stripping the bark from almost any twig, at that season. The cambium is gradually organised into cells, and from these are formed the ducts and cellular portion of the woody layer, and the cellular portion (which is much the greatest) of the layer of bark. Later in the year, the woody tubes grow downwards from the leaves, obtaining nourishment

from the fluid portion of the cambium as they descend; and at last they partly unite themselves with the vessels, &c. of the new woody layer, and, in smaller proportion, with the tissue of the bark.

137. In some kinds of trees, the bark contains a great deal of cellular tissue, and is therefore thick and spongy; this is the case with those that furnish *cork*, which may be regarded as a sort of external pith. The inner layers, however, to which the name of *liber* is given, are usually thin and delicate in their texture, and have been applied to various useful purposes. One of these is indicated by the meaning of the term *liber* in Latin, which signifies *a book;* and thus in that language, a book, and the inner bark of a tree, had the same name. The fact was that, before the invention of paper, the inner bark was one of the substances used by the Romans for the same purposes, as the leaves of the *papyrus* (from which the term *paper* is derived) were employed in Egypt. It is the liber of other trees, which is used by the islanders of the Polynesian Archipelago, for cloth, mats, sails, &c. A very beautiful kind of liber, is that obtained from the Vegetable-Lace tree (as it is called) of Jamaica; when its layers are unfolded, it has the appearance of a delicate lace.

138. From what has been stated, as to the successive formation of new layers within, and the gradual loss of those on the exterior, it is evident that each layer of bark will in its turn be brought to the surface and be thrown off. On the other hand, each layer of wood is gradually being imbedded more deeply. Hence it follows that, if any substance be placed in the newest layer of wood, it will gradually be covered by others; so that, if the tree be cut down at any future time, the number of years that have passed since it was imbedded, may be known, by counting the number of layers on its exterior. On the contrary, if the substance be not driven into the wood, but

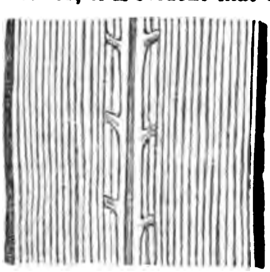

FIG. 59.—VERTICAL SECTION OF A TREE, THE LATERAL BRANCHES OF WHICH HAD CONSECUTIVELY DIED, OR BEEN CUT WHEN THREE YEARS OLD.

remains in the newest layer of bark, it will be gradually brought to the surface and will fall out. Such experiments have been tried, for the purpose of showing the mode, in which these two parts of the stem respectively grow.—In the same manner, it is not unfrequently found, when a tree is cut through, that the ends of the lateral branches, which had either died, or had been cut off, at an early period of its life, are covered by a number of layers of wood, corresponding to the number of years that have subsequently elapsed.

139. As the bark is sufficiently distensible, to admit of the increase of diameter of the interior of the stem, there is no necessary limit to the age of Exogens; and there are many unquestionable examples of such trees having attained an enormous longevity. In this country, the Oak and the Yew appear to be the longest-lived. At Ellerslie, the birthplace of Wallace, exists an Oak, which is celebrated as having been a remarkable object in his time; and which can scarcely, therefore, be less than 700 years old. Near Staines, there is a Yew tree older than Magna Charta; and the Yews at Fountains Abbey, in Yorkshire, are probably more than 1200 years old. Eight Olive trees still exist in the Garden of Olives at Jerusalem, which are known to be at least 800 years old. But the rate of increase in old trees is by no means the same as in young; so that, when they are grown for the profit to be derived from their timber, it is not advantageous to let them pass a certain age. Thus the rate of growth in the Oak diminishes greatly, after about seventy years; that of the Larch, after sixty; and that of the Elm, after about sixty-five.

140. It is in the vessels and woody tubes of the alburnum, that the fluid absorbed by the roots, is transmitted to the opposite extremity of the stem; and these vessels communicate with those of the leaves, which receive it from them. In the liber, on the other hand, the fluid which has been converted in the leaves into nutritious sap, descends again through the trunk, for the purpose of nourishing its different parts. Of this descending sap, a part is carried inwards by the medullary rays; which thus diffuse it through the whole stem, as also through

the substance of the roots, down which it is conveyed by their bark. In this descent, it mixes with the ascending current, especially at its lower part; and being much superior in density, it adds to the density of that fluid, and thus maintains the conditions requisite for endosmose (§. 119). The vessels down which the sap moves in the bark, are of the branching character, described as peculiar to those which convey the nutritious fluid (§. 87). They form a complete network, in which the fluid may be seen to move in various directions. For this motion no definite cause can be assigned. It does not depend on any impulse from above, corresponding to that action of the roots which raises sap in the stem; for there is no power in the leaves to give any such force. It has been supposed to depend upon the gravity of the fluid, which will cause it to descend simply by its own weight; but if that were the case, it would not *ascend*, as it often does, in the bark of the hanging branches of such trees as the Weeping Ash or Willow. It is only one, however, of numerous cases in which a movement of nutritious fluid, through channels in the solid parts it supplies, takes place without any evident cause, in Animals as well as Vegetables. (See ANIM. PHYSIOL. §. 280.)

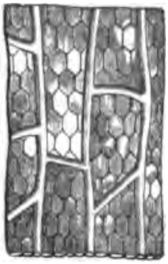

FIG. 51.—BRANCHING VESSELS OF THE BARK.

141. The stem of Endogens is formed upon a very different model. As already stated, the woody bundles in the stem of a year's growth, such as that of the Asparagus, are distributed through the whole of the cellular mass, which originally constituted it; and a similar arrangement would be found in the stem of a Palm, or other aged tree. Instead of being united into rings, these bundles remain separate; and it is only on the exterior of the tree, where they are closely pressed together, in consequence of the continual addition of new woody matter to the interior, that they form anything like hard wood; and even this, though very useful for some purposes, does not possess the kind of texture which adapts it to the work of the artisan. Each annual set of woody bundles, proceeding (as in Exogens)

from the leaves, passes downwards in the softest part of the stem, which is its interior; but after proceeding for some distance in this manner, it turns outwards, and interlaces itself with those which were previously formed. In this manner, the lower part of the exterior of a Palm stem becomes extremely hard; partly from the pressure from within, to which it is not elastic enough to yield; and partly from the constant interlacement of these new fibres, which wind themselves in among the dense tangled mass of the old, like roots seeking to pass through a stone wall. This density is sometimes so great, as to resist the blow of a sharp hatchet.

142. The cellular portion of the stem,—which in Exogens was separated, by the first introduction of wood, into pith and bark,—here remains intermingled with the wood through the whole duration of life, as is shown in the accompanying figure. Each woody bundle contains ducts and spiral vessels, besides woody fibre; and these are arranged in such a manner, that the spiral vessels are on the side next the centre, and are protected by the woody fibre on the exterior. The same elements, therefore, exist in this stem, as in that of the Exogen; but they differ in their mode of arrangement. From their peculiar structure, they increase very little in

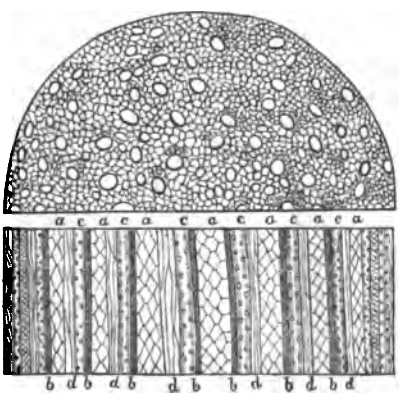

FIG. 52.—HORIZONTAL AND VERTICAL SECTION OF THE STEM OF AN ENDOGEN, showing the bundles of ducts, woody fibre, and spiral vessels, irregularly disposed through the whole stem. *a*, *a*, portions of cellular tissue; *b*, *b*, spiral vessels; *c*, *c*, dotted ducts; *d*, *d*, woody fibre.

diameter, the hardness of the exterior not permitting their enlargement. The consequence of this is, that there is a limit to their age; for the continual addition of new woody bundles to the interior, so much compresses those which were previously

contained in the stem, that they are no longer pervious to fluid, and the tree dies. Nature sometimes provides a remedy for this, in the splitting of the hard envelope, which allows the interior to dilate; and this has been successfully imitated by art,—vigour having been restored to a Palm which had begun to languish, by splitting down the exterior of its stem with a hatchet.

143. Although no complete distinction exists between the cellular and woody portions of the stem in Endogens, yet it is in the interior that the former predominates; and hence some Palm-trees, as that which produces Sago, have been said to have a pith, which is (strictly speaking) erroneous. Through what channels the ascending and descending sap of Endogens respectively move, has not been ascertained; but there can be little question, that it is chiefly through the ducts that the former rises, whilst the latter finds its way downwards through the cellular interspaces. From the cellular portion of the stem, in Endogens as in Exogens, the buds take their origin; whilst the roots are chiefly prolongations of the bundles of wood and vessels. This is well seen in the Pandanus, where the bundles that ordinarily make their way downwards within the stem, and would there form part of the wood, pass outwards and become aerial roots (§. 110).

Fig. 53.

144. The same cause which sets a limit to the age of Endogens, exempts them from the injurious effects, which Exogens often experience, from the compression of their stems by ligatures of various kinds. If a cord be tied tightly round the trunk of an Exogen, it will offer little impediment to the ascent of the sap; but it will obstruct its descent through the bark. In consequence, there will be a deficiency of nourishment to the parts beneath, and a superfluity above; so that a protuberance will arise from the stem, just at the point where the downward flow of the sap is checked. This protuberance will increase in progress of years, if the tree survive, so as almost to bury the cord beneath it; but

most commonly the tree is destroyed, ere long, by the insufficient supply of nourishment to the roots.

145. Now such obstructions not unfrequently arise from natural causes. There are several creeping plants, whose habit it is closely to embrace the stems round which they coil; such is the common Bindweed of this country; and in tropical climates, these creepers are more numerous, and their stems more woody. These seldom wind in complete rings, but in a spiral, growing like a corkscrew; and thus the descent of the sap is rather obstructed than prevented. But an accumulation of the nutritious fluid takes place above the whole line of the spiral: so that, when the creeper is removed, the stem presents the curious appearance of a deep indentation, passing round it from one end to the other; and on the upper edge of this, a corresponding elevation. Endogens are subject to no such alteration; as the sap does not pass down the exterior of the stem, and its diameter increases but little.

146. Such creepers are exceptions to the general rule, that it is the tendency of stems to grow vertically or right upwards. This tendency is sometimes shown in a very curious manner. If the trunk of a young tree be artificially bent, by drawing it (for instance) by a cord to one side, the branch which then most nearly approaches the vertical direction, will increase more than the rest, and will at last appear quite continuous with the lower part of the stem. Again, if the trunk of a tree which usually throws out its branches almost horizontally, such as the Elm, be broken off, the highest branches will gradually approach the upright position, so as to appear like continuations of the broken trunk. In coiling stems, however, it would appear as if some tendency to turn to one side was constantly operating, in conjunction with the upright growth; so that a cork-screw-like form is produced.

147. It is a little remarkable that, though this turn is usually in the contrary direction to that in which the sun appears to move, (as is the case in the common Bindweed, most plants of the Pea tribe, the Passion-flower, the Dodder, and many others,) it is sometimes the same with it, as in the Hop (Fig. 54). Almost

all flowering plants, however, exhibit some tendency to a spiral growth in their stems. It will be hereafter shown, that the *regular* arrangement of leaves on the stems and branches, is in a spiral line. Moreover, in many smooth-trunked species, as the Cherry-tree, the bark is more easily torn off in a spiral than in any other direction. In trees having few branches, such as the Fir, it is not uncommon to see the same tendency manifested by spiral fissures in the wood, when the bark has been for some time removed. The direction of this kind of twist seems to be as constant in straight stems, as in those which manifest it by coiling; thus, the Common Chesnut, and the Horse-Chesnut, have been observed always to twist in contrary ways.

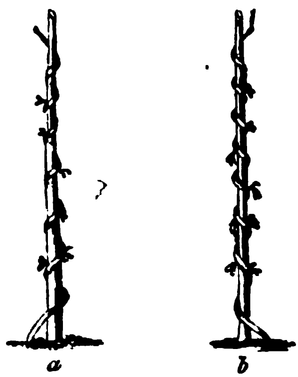

FIG. 54.—TWINING OR SPIRAL STEMS: *a*, French bean; *b*, the hop.

148. The stem is not always solid, either in Exogens or Endogens. Thus among the former, the well-known tribe of Umbelliferous plants presents many instances of a hollow stem, as in the common Hemlock; and in the latter, the Grass tribe affords a corresponding example. In these instances, the hollowness of the stem is due to the expansion of the outer portion, faster than the interior can keep pace with it. The *young* stem is not hollow in either case; and it is a beautiful instance of mechanical contrivance, that, in these rapidly-growing plants, which are to be rendered independent of support from others, the limited quantity of hard tissue which they form, should be disposed at such a distance from the centre, as to give the greatest strength with the least expenditure of material. (See MECHAN. PHILOS. §. 83.) If the material of a Wheat-straw, for example, were disposed in a solid form, it would make but a thin wiry stem, which would be snapped with extreme facility. In the hollow-stemmed Endogens, such as Grasses and Bamboos, and

in many others, as the Sugar-cane and other Canes, we observe certain divisions of the stem, which are called *nodes* or knots. Where the remainder of the stem is hollow, it is always solid here; and the partition has a peculiar degree of firmness, derived from the interlacing of fibres from all sides:—and where the remainder of the stem is filled up (as in the Sugar-cane) with soft spongy tissue, there is still the same kind of firm division at the node. The space between the node is termed the *internode;* and from each one of these divisions, we usually find a single leaf-bud, or pair of leaf-buds, originating. The division into nodes is not so perceptible in Exogens; but it may be regarded as always existing. It is best seen in the young shoots of the Vine; where the fact that, from each internode but a single bud or pair of buds originates, is equally evident. Hence, when the stem itself does not exhibit any distinct division by nodes, the Botanist is accustomed to regard them as existing, near the points from which leaves or branches arise; and to consider as internodes, the spaces between these.

149. Many parts are commonly regarded as Roots, which are in reality Stems. Their position, whether above ground, or beneath the surface, is no criterion as to their real nature. It has been seen (§. 110) that roots sometimes grow in the air; and it is equally true that stems frequently grow in the earth. What are ordinarily called *bulbous roots*, for example, such as

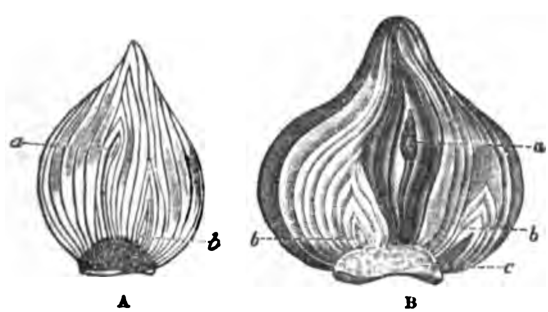

FIG. 35.—SECTIONS OF BULBS: A, Tulip; B, Hyacinth: *a, a,* buds most advanced; *b, b,* buds less advanced; *c,* base of the bulb.

those of the Onion, Hyacinth, Lily, &c., are in reality underground stems. It was formerly stated (§. 111—113) that the real distinctions between the Root and the Stem consist, in the contrary directions of their growth, and in the tendency of absorbing fibres to arise from the former, whilst the latter gives origin to leaf-buds. Now the base of the bulb is the real point of division between the stem and root; for, whilst all below it,—namely the fibres which really constitute the roots,—has a tendency to grow downwards, the mass of the bulb, together with all above it, has a tendency to grow upwards. Further, the *scales* of the bulb are in reality but *leaves*, changed from their usual character and aspect, or *metamorphosed;* and at the base of every one of these scales, is found a little *bud*, occupying the same position in regard to it, as the buds to the leaves on the higher parts of the stem (§. 301). Thus we perceive, that here the stem is in a very contracted state; the internodes not being developed, and the leaves and buds of several nodes arising close together. The difference between one of these scaly bulbs, therefore, and the solid fleshy expansion of the root which constitutes a carrot or parsnep, is at once evident.

150. But stems are sometimes so completely changed, in their direction as well as form, that they can scarcely be recognised as such, except by their producing a regular or symmetrical arrangement of leaf-buds.* Thus they sometimes creep along the ground, or even just beneath it, sending up buds, which develop themselves into branches, at intervals. Of this kind is the *rhizoma* or root-stock of most British Ferns, which creeps above ground in some species, and below in others; and the Ginger-plant of tropical countries has a stem of the same character, which really furnishes Ginger, although this is commonly

* The mere production of leaf-buds does not constitute a sufficient character to separate stems from roots; for a great number of roots, when exposed to the air, or when very near the surface, will give origin to leaf-buds. Elms and many fruit-trees afford familiar examples of this fact. Besides, one very common mode adopted by Gardeners for propagating some plants (such as the Pelargoniums), is to cut a portion from the root, and put it in the ground, leaving the upper part uncovered; from this, in a very short time, a number of leaf-buds show themselves; but these are without any regular arrangement.

spoken of as the *root* of the plant, being partly buried be-

FIG. 56.—CREEPING STEM OF FERN.

neath the ground. The *runners* of the Strawberry, again, are but trailing stems; which send down roots, and develop buds, at intervals, and thus extend the plant. This tendency, which is serviceable to Man in this instance, is very troublesome to him in another; for in the same manner, the Couch-grass overruns pasture lands, exterminating, if its increase be not checked, their original vegetation. As every internode of these trailing stems possesses the power of developing both roots and buds, it is useless to attempt to destroy the plant by chopping the stem into pieces; for this is in reality only multiplying it. It is well to mention, however, that though usually regarded as a very rank weed, the underground shoots of this plant constitute a peculiarly nutritious food for cattle.

FIG. 57.—AN AQUATIC PLANT EXTENDING ITS STEMS IN THE MUD.

151. One of the most distorted forms of the Stem, is that which presents itself in the Potato. This plant grows with an underground stem, sending up its flowering branches into the air, and sending its roots downwards into the earth; but on this stem it forms at intervals the *tubers* or knobs, which constitute such

an important article of food to Man. That these tubers are still parts of the stem, is shown by their power of originating buds, from the points commonly known as the *eyes* of the Potato. When, therefore, we divide the tuber into pieces, keeping an eye in each, from every one of which we expect a young plant to spring, we follow in fact the same plan, as that adopted in planting Sugar-Canes; which are not propagated from seed, but by dividing the stem into its internodes, and laying each of these separately in the ground. And thus it is seen, that the division of the creeping stem of the Couch-grass, effects in reality the same end. The quantity of fleshy matter deposited in the Potato, serves for the nourishment of the growing buds before their roots are formed; and thus it is that, if exposed to a warm and moist atmosphere, they are liable to sprout, without the contact of earth. It is remarkable that, in their native climate (the tropical part of South America), the tubers of the Potato are extremely small; and that they become so, when plants are raised from British stocks, in any countries equally hot.

152. In all these instances it is seen, that not only buds, but roots, may arise from different parts of the stem and branches. But this tendency is by no means confined to such as grow on or beneath the ground. There are many trees, of which the branches naturally hang downwards; and if these reach the ground, they give origin to a new set of roots, which serve for their own nourishment, and for that of the shoots they send off, so that they become so many secondary stems. The most curious examples of this kind are the Banyan trees of the East Indies, of which one individual sometimes constitutes a miniature forest. The most celebrated specimen is that of Cubbeer-bur; which, many years since, possessed 350 principal trunks, and smaller stems amounting to more than 3000; every one of which was casting out new branches and hanging roots, to form future trunks. The space of ground which it covered was such, that it was estimated that 7000 persons might have found ample room to repose beneath its shade. These trees are held by the Hindoos in superstitious reverence, and are dedicated to religious observances. Our own sacred poet, Milton, has given a beautiful delineation of them:—

"The fig-tree: not that kind for fruit renowned;
But such as at this day to Indians known
In Malabar or Deccan, spreads her arms,
Branching so broad and long, that in the ground
The bending twigs take root, and daughters grow
About the mother-tree, a pillar'd shade,
High overarch'd, with echoing walks between."

153. The only Cryptogamia at present existing, which form true woody trunks, are the Tree-Ferns of tropical climates. In these, the stems which creep along or under the ground, in the species inhabiting temperate climates, erect themselves into the air, and bear a beautiful crown of leaves. These stems are sometimes hollow, and sometimes contain a sort of spongy pith. Their mode of growth is different from that of either Exogens or Endogens; and appears of a simpler character. The stem, when cut across, is seen to consist of a number of hard woody plates, adhering rather loosely together; and these, if traced upwards, are found to be either continuations of the flattened footstalks of the leaves which crown the summit, or to be the remains of those which have dropped off. Every year, the leaves decay away, and are replaced by a new set formed above; so that the stem continues increasing in length, but undergoes little change in diameter. The marks seen on the exterior of the trunk, are the scars of the former leaves; and by the relative position of these, it is seen that, though the portion of the stem first formed increases but little in diameter, it receives some addition to its length,—its scars being separated from each other by a much wider interval, than in the newly-formed part. However, it is the general rule, in these and other Cryptogamia, that the portions first produced undergo little subsequent change; hence, whilst the names Exogens and Endogens are used, to indicate the modes of growth respectively peculiar to the two chief divisions of Flowering plants, the Flowerless plants may be included under the general term ACROGENS, which intimates growth by the point, or by addition to the extremities only.

FIG. 58. — PORTION OF THE STEM OF A TREE-FERN.
a a, scars of former leaves.

CHAPTER VI.

OF THE FOOD OF PLANTS, AND THE MANNER IN WHICH IT IS OBTAINED.

154. A PLANT or tree can no more exist without *food*, than can an animal; and it is only because the mode in which they receive it is less evident to us, that we do not commonly think of Vegetables, as equally dependent with Animals, upon the materials supplied to them by the elements around. We are constantly witnessing the act of feeding, in all the Animals that are under our notice; but the growth and reproduction of Plants *seem* to take place, with so slight an introduction of solid matter into their system, that it cannot be comprehended without further examination, how they derive the means of uprearing the gigantic masses of wood and foliage, which many of them present to our admiring view. It cannot be shown, that any solid matter is ordinarily taken up by the roots, except certain mineral ingredients which most plants require, and the use of which will be presently stated; these, too, must be dissolved in water, before they can be imbibed. How, then, do they obtain the materials of the firm wood of their stems, roots, and branches,—of the soft but still firm tissue of their leaves and fruits,—of the fleshy seeds they generate in their flowering system,—and of the various hard substances which they produce in their different tissues? This question will now be answered.

155. In the first place it may be laid down as a fact beyond doubt, that neither Plants nor Animals have the power of creating or producing matter, which did not before exist. Living beings are entirely dependent upon the supplies they obtain from without, for the maintenance and enlargement of their own

structures;—they greatly alter the form and properties of the elements they take in;—but they can *create* nothing. It is easy to say whence every particle, of which a living body consists, is obtained by it; for, by placing it in a variety of circumstances, and observing the changes in its mode of life which these produce, we can determine the influence of each. Thus, an Animal may be fed exclusively on some one kind of aliment, as for instance sugar or gum; and it is found that, however nutritious when combined with others such an article may be, it has not the power of supporting life for any length of time by itself, unless it contain (which no single article of food except *milk* does) *all* the substances required by the animal, for the right maintenance of its structure. So, also, on the food of Plants we may experiment, by placing them in different soils, and in different kinds of air, and by supplying them with variable quantities of water; until we have discovered, what is absolutely necessary to their growth,—what favours it,—and what is superfluous or injurious.

156. Before, however, we enter upon these inquiries, we shall derive much guidance, from the knowledge of the substances actually contained at any given time, in the Vegetable structure. When we examine a seed, we find that it contains the germ of the new being; but that it principally consists (like the egg) of a nutritious substance, prepared by the parent, for the support and development of its offspring, until it is able to acquire food for itself; and it is by this means, as we shall hereafter see (Chap. XII.), that the young plant is enabled to push its first roots into the soil, and to elevate its first leaves into the air. By the time it has done this, however, all that store of aliment is exhausted; and henceforth it is entirely dependent upon what it acquires for itself. The lowly plant develops itself in progress of years, by the wonderful power with which it is endowed, into the gigantic tree; increasing its weight, from a few grains to many tons. Of what does its massive structure then consist?

157. The inorganic elements and mineral matter, composing the solid earth on which we live, contain a certain number of substances, which are termed *simple;* because they cannot, by

any known chemical process, be shown to consist of others united together. Such, to take familiar examples, are the various metals, with sulphur, iodine, as well as many other less common bodies. But the greater part of the substances which surround us, are termed *compound;* because they can be separated into two or more simple or elementary bodies. Limestone, for example, when exposed to heat, is much changed in its character; it gives off a kind of gas or air, termed *carbonic acid* gas; and *lime* remains—a substance which it is no longer safe to handle, on account of its possessing the power of destroying (or, as commonly said, burning) animal flesh, whence it is commonly termed quick-lime. But neither of these two substances are simple; for it is easily shown, that carbonic acid is composed of two others, of which one is *carbon*,—a solid substance of which the diamond is the purest form, but which is nearly the same with charcoal; whilst the other is *oxygen*, a gas which forms part of the air we breathe. Again the lime may be shown (by a process of much difficulty) to consist of a metal, termed *calcium*, united with some of this same *oxygen*.

158. Carbonic acid is the gas known as *fixed air*,—or in mines as *choke damp*. It is very injurious to the life of animals, acting as a sort of poison to them. It is formed during the combustion or burning of every substance containing carbon; for this combustion really consists of the union of carbon with oxygen, which, when it takes place rapidly, is accompanied by light and heat. Thus, if a pan of charcoal be burned in a closed room, a large proportion of the oxygen of the air will be converted into carbonic acid; so that any human being, and almost any air-breathing animal, would rapidly lose his life in such an atmosphere. In this manner many persons have been suffocated. Charcoal, however, is not the only form in which carbon exists; coal contains a very large proportion of the same element; and carbonic acid is accordingly formed by its combustion. It also exists in the gas now so commonly used in towns for lighting, which is usually made from coal, though sometimes from oil; this gas consists of carbon in union with *hydrogen*, another kind of element presently to be noticed; and when it is burned it

forms carbonic acid, together with the vapour of water, which is produced by the union of the hydrogen with the oxygen of the air.

159. Carbonic acid gas is also given off by all Animals, which form it during the process of respiration or breathing; for a portion of the oxygen which is taken into the lungs, is there combined with carbon, which the animal system wants to throw off, and then breathed out again in the form of carbonic acid (See ANIM. PHYSIOL. Chap. VI.). The presence of this gas in the air returned from the lungs, is easily shown by breathing out through a tube, the end of which is immersed in a deep glass containing lime-water, which is water having a small quantity of quick-lime dissolved in it. After the lungs have been a few times emptied through this tube, the water becomes quite turbid, by the union of the carbonic acid with the lime, and the consequent formation of a carbonate of lime; which, not being soluble in water, falls as a white powder, resembling pounded chalk. It will be hereafter shown that Vegetables, like animals, form carbonic acid during the whole course of their lives; by causing the oxygen of the air, surrounding them, to combine with the carbon which they have to give off (Chap. VIII.).

160. Now the carbonic acid thus combined with the lime, might be separated again by heat, or in other modes. If we pour a little vinegar upon limestone or chalk, a bubbling or effervescence is produced; which is caused by the acid of the vinegar combining with the lime, for which it has a greater attraction than has the carbonic acid; and as they cannot both be combined with the lime, the latter is set free. It is liberated, also, in large quantities, during the process of fermentation; and this it is, which renders it dangerous to walk over a vat in which fermentation is going on, and which extinguishes a candle held in such a situation. Putrefaction, too, is a kind of fermentation; and carbonic acid is given off in this process. In fact, the respiration of Plants and Animals may be regarded as designed to carry off the carbonic acid, produced by a kind of slow putrefaction or decomposition, which is always going on within the body: for it is a peculiar characteristic of the compound sub-

stances, of which vegetable and animal structures are made up, that they have a tendency to separate themselves into their elements, under the ordinary circumstances of warmth, moisture, &c., to which mineral bodies may be exposed for centuries without change. This tendency to separation it is, which causes the decay of animal and vegetable substances after death; for the elements that were previously combined, in ways which no chemical processes can imitate, then pass off in simpler forms, of which carbonic acid is one of the chief.

161. Different parts of the Animal and Vegetable framework display this tendency in varying degrees. Thus the bones of an animal, and the heart-wood of a tree, may remain almost unchanged for centuries, and thus exhibit nearly the same permanence as the limestone rock; whilst the soft flesh of the animal, and the pulpy portions of the plant, pass into decomposition almost immediately upon the death of the being. This decomposition, however, is chiefly remarkable after death; only because it is not then counteracted by the processes, which form an essential part of the functions of life. The object of those functions, is not only to provide for the *growth* of the structure, and for the production of new individuals which shall continue and extend the race; but to maintain in constant perfection and vigour the parts already formed. This is accomplished by the removal of the portions, which have exhibited the slightest tendency to decay; and by the deposition of freshly-formed substances, of a similar character, in their place. The particles which are removed, are carried off in the blood of the animal or the sap of the plant; and are separated from this in part by the process of respiration, which gets rid of the carbonic acid, and in part by other means of a corresponding nature.

162. The rapidity of these processes of deposition and removal, in the several parts of the living body, bears a very close proportion with the natural tendency to decay, which they respectively manifest. Thus, the bones of an Animal are in general sparingly supplied with blood, and seem to undergo little change, except as the result of disease or injury; but the supply of blood is greatly increased, when any circumstances demand a new formation of

this tissue. So, in the heart-wood of a Plant, the circulation almost ceases; for so long as no air or moisture from without, find access to the interior of the stem, this part retains its firmness unchanged, and its particles require no renewal.—But the soft tissues of an Animal are largely supplied with blood, and also with absorbing vessels; and the greatest part of the food taken in by one which has attained its full growth, is devoted to the maintenance of these parts in their right condition, which is essential for the proper performance of their functions. Of all these soft tissues, that which forms the brain and nerves is supplied with the largest proportion of blood, and undergoes the most rapid changes during life; and it is this which most speedily decomposes after death. The soft tissues of Plants do not so quickly decay as those of animals, and the circulation of nutritious sap through them is less active; but still a movement of fluid takes place, and the same object is attained by it.

163. Thus we perceive that *food* has for its object,—in the first place, to supply the materials of the growth and extension of the system, enabling the minute germ containing the seed to develop itself in time into a lofty tree;—next, to maintain the parts so formed, in their healthy state; by affording the materials by which those that have begun to decay may be replaced; —further, to provide a store capable of supplying the occasional extraordinary demand for reparation, which disease or injury may produce;—and, lastly, to enable the being to develop the germs of new individuals; and to supply them with a store of nutriment, on which they may live, until able to provide for themselves. Now of the 55 simple substances into which the solids, fluids, and gases, of the inorganic world may be separated, Vegetables are principally made up of four; and of these only three exist in any large proportion. These three are carbon, oxygen, and hydrogen; and the fourth is nitrogen. It appears, from recent inquiries, that the *organised tissues* of Plants,—that is, their cells, fibres, vessels, &c., freed from their contents—are composed of a substance, which everywhere possesses the same composition; and that this consists of 24 Carbon, 20 Hydrogen, and 10 Oxygen, without any Nitrogen. The composition of

Starch, which, as we shall hereafter see (Chap. IX.), performs offices of great importance in the vegetable economy, is precisely the same. On the other hand, the substances into whose composition Nitrogen enters, though very generally diffused through the tissues of the Plant, do not seem to undergo organisation, but to form part of the *contents* of the cells, vessels, &c., of which these tissues are composed.—It is curious to remark, that precisely the reverse is the case with Animals; *their* tissues being composed of a substance containing nitrogen; and substances which are destitute of it being never found in their bodies in an organised state, but only existing there in the cavities of their cells, tubes, &c. (See ANIM. PHYSIOL., §. 16, 154).

164. Of all these, CARBON is by far the most abundant. It is, as already mentioned, nearly identical with *charcoal;* which consists of the carbon of the wood, mixed up with a small quantity of earthy matter. If this charcoal be burned, it passes off in the form of carbonic acid gas, leaving a minute portion of white ash, which is principally of a mineral nature. It is chiefly to the carbon which it contains, that the hardness and solidity of wood are due. In so large a proportion does it exist in that tissue, that, when the other elementary bodies (the oxygen and hydrogen) have been separated, the carbon retains the form of the tissues in great beauty and perfection; so that a section of a piece of charcoal, will indicate the character of the wood from which it was made, nearly as well as would a section of an unburnt branch. On the other hand, in proportion as the tissues of the Plant are deficient in carbon, do we find them deficient in firmness of structure.

165. When we consider the large quantity of carbonic acid, extricated by the respiration of Animals, and by the immense amount of combustion of Coal, which is constantly going on in our large towns, there would seem no difficulty in understanding how it may be supplied to Plants; but so vast is the extent of the atmosphere, through which the carbonic acid has to be diffused, that any given bulk of air only contains about 1-1000th part of this gas. Hence it might be supposed impossible, for

the gigantic mass of carbon contained in the wood of a wide-spreading forest, to have been derived chiefly, if not entirely, from this source; and yet such will be seen to be the case. For, although the soil may contain carbon, none of it is taken up in a solid form; and its quantity rather increases than diminishes in the course of years.

166. OXYGEN is contained largely in Plants; and the presence of it in the air which surrounds them, is very necessary to their healthful existence,—chiefly as affording the means by which, as already explained, the superfluous carbon is removed. This element is equally necessary to animals; and it constitutes about a fifth part of the air we breathe. A portion of this air is dissolved, as it were, in water; and it is in this manner, that fishes and other aquatic animals, as well as aquatic plants, are supplied with oxygen. Most, if not all, however, of the oxygen, which is contained in vegetable substances, is taken up by them, either in combination with carbon, or in union with hydrogen,—a body which, with it, forms water.

167. HYDROGEN is also contained largely in Plants; and, in most of the substances into whose composition it enters, it is combined with oxygen, nearly in the same proportion as in water. Although it is probable that a small quantity is introduced with nitrogen in the form of *ammonia* (the pungent gas which gives strength to hartshorn, smelling salts, &c.), we may regard the *water* introduced into the substance of plants by their roots, and also in part absorbed by their general surface, as the chief source of this element, as well as of the oxygen contained in the vegetable structure.

168. NITROGEN has not been commonly regarded as an important element of the Vegetable structure; but it has been lately shown to exist largely in certain parts of plants; and there seems reason to believe its presence to be essential to the increase of their fabric, by the formation of new parts. It is an important ingredient in the substance called *gluten*, which is identical in its chemical composition with the Albumen, which is the basis of the Animal tissues (ANIM. PHYSIOL. §. 153); this gluten exists largely in the seeds of the various kinds of corn, and most of all

in wheat; and it is in part on this account, that wheaten bread is the most nutritious of all vegetable substances ordinarily used as food. It is, indeed, on account of their entire deficiency in nitrogen, that gum, sugar, and other similar products, are not fit to maintain animal life by themselves (see ANIM. PHYSIOL. §. 155). Nitrogen constitutes four-fifths of the atmosphere; but it does not seem to be taken in by the Plant in its simple form. This gas with hydrogen forms *ammonia*, of which a minute quantity always exists in the atmosphere, being chiefly supplied to it by the decomposition of animal matter; and this is absorbed by the soil, and taken up by the roots, in the manner hereafter to be described. It is in the supply of ammonia which they yield, that the principal benefit of animal manures seems to consist.

169. Besides these elementary substances, which all Plants contain, and of which the vegetable tissue may be regarded as essentially consisting, almost all plants contain some mineral ingredients, the presence of which is necessary to their healthy existence. These remain as ashes, when the other parts of the structure are set at liberty by combustion;—the *carbon* uniting with the oxygen, and with some additional oxygen from the air, passes off as carbonic acid;—of the *hydrogen*, part unites in the same manner with oxygen, and passes off as watery vapour;—the *oxygen* is thus entirely carried off;—and the *nitrogen* unites with the remainder of the hydrogen, to form ammonia. Thus there remains nothing of the vegetable tissue, but the incombustible matter; and the nature of this varies in different plants. Thus, in the Grasses (including Corn, Bamboo, Sugar Cane, &c.), the ashes consist principally of minute particles of flint. In most other plants growing inland, we find some compound of the alkali potash; and it is from this source, that the greatest quantity of the *pearl-ash* that is largely used in various manufactures, such as soap and glass, is derived. On the other hand, in plants growing near the sea, the potash is replaced by soda, which has nearly similar properties. Again, in most plants, there is a small quantity of carbonate of lime, and in others there is a large quantity of lime combined with other acids; thus, in Rhubarb we find large crystals of oxalate of lime; and in the Corn-grains

there is a considerable amount of phosphate of lime, by which their power of nourishing Animals is greatly increased, since this substance constitutes the earth of bones.

170. Of these different mineral ingredients, each Plant seems to have some one or more, that are as essential to its growth, as is any other article of its food; but the quantity required is sometimes extremely minute, so as to be scarcely detectible,—only a very small quantity of ash remaining, after the tissue has been burned. In other instances, again, the mineral matter is so abundant, as to present itself in the form of large crystals, which are deposited between the cells of the tissue. But that which seems its proper office, is to form part of the membranous walls of every cell and tube of the whole structure, however delicate these may be. If a thin portion of almost any plant, be burned in such a manner, that free combustion of all its gaseous elements may take place, without disturbing the place of those which remain, a beautiful skeleton, consisting of extremely minute particles of mineral matter, will be seen, in which the form of all the cells, vessels, &c. may be distinctly traced. These particles would seem to be dispersed throughout the minutest parts of the vegetable tissue; and they probably serve the purpose of conferring additional strength upon the delicate framework of which it consists. Even in the finer ashes left by the combustion of common coal, a person to whom the forms of the elementary tissues of plants are familiar, will often succeed in detecting with the microscope, fragments of such skeletons; which thus add to the evidence—otherwise sufficiently strong, of the Vegetable nature of that substance.

171. Now that we are acquainted, therefore, with the elements of which the Vegetable structure is composed, and have some knowledge of the sources whence these are derived, we are prepared to inquire more minutely, into the manner in which they are severally received into the organism, and made parts of its structure. This is an inquiry of the highest consequence in Agriculture,—an art which, as it has been justly observed, is superior in importance to every other, since on it Man entirely depends for his subsistence, and in great part also for the wealth

and power obtained by commerce, and for the materials of his various manufactures.

172. From what has been stated, it would appear that water, carbonic acid, and a minute quantity of ammonia, supply the ingredients of the new compounds, which are formed in the living Plant; but that, in most cases, mineral substances of some kind are required in addition. There are some plants which derive a sufficient quantity of all these elements, from the atmosphere alone; so as to be able to maintain life, and even to flourish, without any other kind of supply. The water is absorbed by the general surface, but especially by the roots, which in such plants are usually long, and of soft tissue throughout; the carbonic acid is taken in through the green parts from the atmosphere alone, in the manner which will be described in the next Chapter; and the minute quantity of ammonia, also contained in the atmosphere, which is probably dissolved in water and taken up with it, affords a sufficient supply of nitrogen. Such aerial plants usually contain but a very small quantity of mineral matters; and these, too, are probably derived from the atmosphere, in which, as will be hereafter mentioned, their particles are suspended.

173. These aerial plants, clustering round the branches of lofty trees, and hanging to a great depth beneath them, are extremely common in tropical climates; in which the atmospheric moisture is much greater, and where they constitute an important part of the vegetation; and they are not wanting in this country. Many trees and plants, which do not ordinarily grow in this manner, may be caused to do so by accident or design; and may even thrive extremely well. At New Abbey, in Gallowayshire, in the year 1817, there was growing on the top of a stone wall which measured ten feet in height, a Plane tree, which measured twenty feet in height; and, as it soon exhausted the bare and scanty soil in which the young plant grew, it sent down roots which clung to the side of the wall, and threw out neither bud nor branch until they reached the ground, which was not until several years had elapsed; during all this time, the tree must have lived upon the materials supplied by the atmosphere alone.

174. In one of the hot-houses in the Botanic Garden of Edinburgh, a plant of the Ficus Australis (the Fig of New Holland) was caused to grow entirely without earth, by gradually withdrawing from the pots the several roots contained in them. The plant was well watered twice a day, and put out roots freely from all parts of the stem and branches, by which it appeared to gain an ample supply of nourishment; for it produced a very full crop of fruit, in the autumn after the earth was removed from the last set of roots. Even when a plant attaches itself by roots to the soil or rock, these may serve only for its support, and may not contribute anything to its growth.

175. Many succulent Plants of warm climates exist in this manner; clinging to the faces of the barest cliffs, or rising out of the most dry and barren sand; deriving their supplies of moisture and other aliment, therefore, entirely from the atmosphere. It is interesting to remark, that most of these plants contain in their juices the substance caoutchouc (commonly known as Indian-rubber) and also wax; and the moisture obtained from the atmosphere is prevented from evaporating (which even the thick cuticle would not prevent it from doing, under the influence of a burning sun), by a thin layer formed by the drying of these juices around them; which, like a waterproof cloak, keeps in the vapour that would otherwise be raised, so that the tissue of these plants becomes turgid with their juices, although so little is absorbed.

176. But the majority of Vegetables require a larger and more certain supply of their various kinds of aliment, than the atmosphere can furnish; and, by the prolongation of their roots into the soil, they are enabled to obtain this,—in a manner, however, which requires some little explanation. What is commonly termed *soil* or *mould* consists of two kinds of ingredients;—it is partly composed of the materials of the rock beneath, the particles of which are gradually separated from each other, by the action of the atmosphere, of water, and of the roots of growing Plants, as formerly explained (§. 108);—and partly of the remains of former races of Plants, which are in process of decay. The former sometimes exist almost alone; and the latter, in land

which has long been cultivated, often constitute a very large proportion. The two together, or either singly, will form *a soil;* the first use of which is to afford to the plant the power of affixing itself, so as to raise its stem, leaves, and flowers, into the most direct influence of the air and light. The next object which it should fulfil, is to supply the roots with a sufficient and regular amount of water; and this will be effected, according as it is capable of imbibing water readily, from the atmosphere, and from the neighbouring springs, ponds, or streams.

177. Soils may be divided into the clayey, the calcareous (those containing much carbonate of lime), and the sandy. A stiff soil opposes the ramification of the roots, whilst a sandy one does not afford them sufficient hold; it follows, therefore, that no plants will grow advantageously in the former, but those whose roots do not naturally extend far, and whose vegetation is slow; whilst those are most suited to a sandy soil whose roots spread extensively. It is by means of the *Arundo arenaria* or Sea-reed, that the Dutch attempt to check the progress of the drifting sand-hills, which threaten desolation to large tracts of country; and when the soil is once fixed by it, and improved by the decay of the individuals first produced, it affords support to vegetation of more value.

178. Again, every one knows that a stiff clay will retain its moisture for a long time; and that it parts with it, or receives more, with much difficulty; whilst, on the other hand, a sandy soil absorbs much water, but soon loses it again. In climates where rain occurs pretty often, a calcareous soil is usually preferred, as retaining its moisture sufficiently long, and yielding it with facility; if, however, the temperature of a country be high, and rain fall but rarely, a stiff soil is preferable, as it will not become dry in the intervals; whilst, on the other hand, a sandy soil answers better in a region where showers frequently descend. The defects of one soil, in regard to its power of supplying vegetation with moisture, may be in some degree remedied by admixture with another; this process is called in agriculture the *tempering* of soils. Thus, a stiff clayey soil may be tempered by mixing with it chalk, ashes, or sand, by which it is rendered

more permeable to water; whilst, on the other hand, a loose sandy soil may be advantageously tempered with clay.

179. The supply of moisture to the roots, however, is not the only important object, which the soil should answer. It ought to afford carbonic acid also; since it is essential to the rapid growth of a Plant, that this part of its nourishment should be taken in by its roots, as well as by its leaves. The carbonic acid may be furnished in two ways; either the soil may absorb it from the atmosphere; or the decay of some of the matter contained in it, may disengage this product. There is a remarkable property possessed by several porous substances, of absorbing gases, and especially carbonic acid gas, to the amount of many times their own bulk. (See MECHAN. PHILOS., §. 33.) Of all these, charcoal is one of the most powerful in this respect; and it has been found, that many plants may be grown in powdered charcoal, if sufficiently supplied with water, more luxuriantly than in any other soil. The charcoal itself undergoes no change, but it absorbs carbonic acid gas from the air: this is dissolved by the water which is taken up by the roots, and thus it is introduced into the system. In such cases, the plant derives its solid matter as completely from the atmosphere alone, as if its roots were entirely exposed to it; for not a particle of the charcoal is dissolved, and *it*, therefore, affords no nutriment to the plants.

180. It may be thought incredible that the enormous quantity of carbon, which enters into the composition of a single tree, —much more of an extensive forest, and much more still of the immense succession of such luxuriant forests, as those which formed our beds of coal,—should ever have been contained in the atmosphere; since any given quantity of air contains only about one-thousandth of its weight of carbonic acid; and this gas is composed of only about 27 parts of solid carbon in every 100. But it must be remembered that, as the weight of the air pressing upon every square inch of the earth's surface is 15lbs., that pressing upon a square foot will be 2160lbs.; and as the surface of the earth can be almost exactly calculated, it may be shown that, in the whole of the atmosphere surrounding it, at

least three thousand million million pounds of solid carbon must be contained,—a quantity which amounts to more than the probable weight of all the plants, and of all the beds of coal, which exist upon the earth. The quantity of carbon existing, in various states of combination, in sea-water, is proportionably greater.

181. The readiness with which the atmosphere yields a large quantity of carbonic acid, to any substance having a strong attraction for it, is shown when the walls and ceiling of a room are white-washed, or coated with a thin layer of quick-lime. This coating becomes very speedily converted, by combination with the carbonic acid of the air, into carbonate of lime. It may be thus shown, that the atmosphere is capable of yielding to a coating of lime, extended over a given surface, and renewed as fast as it is converted into carbonate, a quantity of carbonic acid three times as great as that, which is taken in by the leaves and roots of plants, growing upon a similar surface during the same time.

182. The constant maintenance of this ingredient in the atmosphere, so as to supply the enormous drain upon it, which active vegetation induces, is owing to changes of an opposite character taking place as constantly. Every Animal is incessantly engaged in converting the oxygen of the air into carbonic acid, by the process of respiration or breathing. Of the solid carbon taken in by it as food, which is all derived, either directly or indirectly, from Vegetable matter (since every Animal is supported either upon Vegetable substances, or upon the flesh of other Animals which subsist on them), a portion is constantly being restored to the gaseous form in this manner. A single Man daily converts nearly 18,000 cubic inches of the oxygen of the air into carbonic acid, by the carbon disengaged from his lungs (ANIM. PHYSIOL., §. 334); and the enormous amount that must be daily formed, by the whole human and animal population of the globe, may thus be perceived. Again: the combustion of vegetable substances,—coal, wood, &c.—is a vast and continual source of the renewal of the supply, drawn by vegetation from the atmosphere. It has been calculated that the small town of Giessen in Germany, possessing a population of

about 7000 inhabitants, yearly converts more than 1000 million cubic feet of oxygen into carbonic acid, by the combustion of wood as fuel; and in an English manufacturing town, where the proportion of coal used is far greater, the amount would be at least twice as much in proportion to the size.

183. Now if it were not for the constant check, which the processes of vegetation afford, to the accumulation of this ingredient in the atmosphere, it would go on increasing, until the air became unfit for the support of Animal life. But it is the fact, ascertained by the careful examination of the air preserved in some empty jars which had been buried with the city of Pompeii, that the proportion of the gases composing the atmosphere, can be proved to have undergone no change during the last 1800 years. It is scarcely possible to contemplate all this wonderful system of mutual action, upon a scale so immense, without being struck with the simplicity and harmony of the design, and the perfection with which it operates. The Plant is constantly withdrawing from the atmosphere its carbon, and converts it into the material of its own solid structures. Of the substances thus produced, a part is employed as food for Animals and Man, a part serves as fuel, a part is applied to various purposes in arts and manufactures, and a part decays without being removed from the place where it grew. Now nearly all the carbon taken in as food by Animals, is restored in a gaseous form to the atmosphere, either by the process of breathing during life, or by the decomposition of their tissues after death;—all that is used as fuel is converted into carbonic acid gas,—as does nearly all that decays where it grew;—there only remains, therefore, the amount employed, chiefly in the form of timber, for various purposes by Man; and this is more than supplied, by the combustion of that which has been stored up ages ago for his use, in the form of coal.

184. It is from the decay of Vegetable and Animal matter, that Plants (at least under ordinary circumstances) derive whatever supply of carbonic acid they obtain, in addition to that afforded by the atmosphere. Vegetable mould consists of decaying portions of the tissue of plants; and is constantly libe-

rating carbonic acid, in the progress of its decomposition. This is dissolved by the fluid of the soil, and is taken up by the roots. The supply of carbonic acid thus obtained, seems chiefly important to the plant, when its leaves are undeveloped; as is the case in the early stages of its growth, as well as in every succeeding spring, with all but evergreens. For it will hereafter be shown, that it is almost entirely through their leaves, that plants obtain carbon from the atmosphere; and when these are fully expanded, the absorption of carbonic acid by the roots may be dispensed with.

185. But the decomposition of the Vegetable matter of the soil, requires the free access of air to every part of it. If any substance, however rapid its tendency to decay, be completely secluded from the atmosphere, little or no change in it will take place.* Every particle of the soil needs to be surrounded with oxygen, for the production from it of carbonic acid; and to produce this condition, is one of the chief objects which is effected, by tilling and loosening the soil. In this respect it is manifest, that a clayey soil is inferior to all other kinds; and its injurious character can only be remedied, by admixture with other substances, or by laborious cultivation. The necessity of unimpeded access of air to the part of the ground, through which the roots are distributed, is shown in an interesting manner, when trees are planted too deep in the soil, or when their roots have been covered with an additional quantity of earth. If the tree be old or sickly, it generally dies; but if it be vigorous, it sends out a new set of roots nearer the surface, and the extension of the old ones ceases.

186. Notwithstanding, however, the gradual conversion of the carbon contained in vegetable mould, into carbonic acid, and the absorption of this by the roots, the quantity of carbon in a soil which supports a flourishing vegetation, is progressively increasing, rather than diminishing. The addition takes place in several ways. The roots themselves throw out (as already

* It is on this principle, that various articles of food are now preserved for subsequent use, in tin cases completely closed; and possess their perfect flavour, after exposure to all varieties of temperature, for several years.

stated, §. 119) a considerable amount of matter, formed in the vegetable itself, and corresponding in character with its peculiar secretions; and this gradually undergoes decomposition, furnishing a large proportion of carbon. The leaves of plants which fall in the forest in autumn, and the old roots of grass in the meadow, are likewise converted into a rich vegetable mould, capable of yielding a large supply of carbonic acid; and thus it becomes evident, that plants must absolutely derive more carbon from the atmosphere, than they fix in their own tissues, since they are continually increasing the amount of vegetable mould on the surface of the earth.

187. Thus we perceive, that no matter which has been organised, can serve as the food of Plants, until it has undergone decomposition; and that it is solely in the constant and regular supply of carbonic acid it affords, that vegetable mould is more adapted for the support of vegetable life, than any other kind of soil. If we could form a soil of mineral substances only, in every portion of which carbonic acid should be slowly liberated, and which would be equally fit in other respects, Plants would flourish quite as well in it. And thus we see a very important difference in the characters of the Animal and Vegetable Kingdom; for, whilst the beings of the first group are entirely dependent for their nourishment, upon matter that has been previously organised, and thus derive their support either from animal or vegetable bodies,—those of the latter are dependent for their growth, only upon the materials supplied by the inorganic world, although their increase may be advantageously assisted and stimulated, by those which they derive from the decay of the former.

188. And here again do we trace a beautiful harmony, between the various parts of the grand scheme of Creation; for had Vegetables been dependent, like Animals, upon organic matter, both classes of beings must have gradually disappeared from the face of the earth, since the spontaneous death and decay of a large proportion of them, is constantly restoring to the inorganic world, the elements they have for a time held, in those peculiar forms of combination which are termed organic; and thus the

amount of organic matter would be continually diminishing. But Vegetables, holding an intermediate station between the Mineral and Animal creation, bring them, as it were, into connexion with each other; preparing, from little else than the air and the water of the globe, the materials for the sustenance of the countless millions of beings, which move upon its surface, and which, when their allotted period of existence has expired, restore, by their decay, the elements that are required for the support of Vegetable life.

189. No organic substances can be said to serve as food to Vegetables, in the same manner as to Animals; for they all need to be separated into nearly their simplest forms, before they can be reunited into the peculiar compounds, which are required by the tissues of the Plant for their nourishment and extension. If it were otherwise, we should expect that those would act as most serviceable manures, which are most similar in composition to vegetable tissue; just as animal flesh is the most easily digested, of all food, by the animal. But this is not the case; for the richest manures are well known to be those, which (supplying also certain ingredients presently to be mentioned) are continually evolving, by their decay, a large quantity of carbonic acid. It is in part, by hastening the separation of the elements of some substances, which might otherwise resist decay for a long time, that lime acts as a valuable manure; and yeast is a still more powerful agent of the same kind, occasioning a kind of fermentation in the vegetable matter of the soil, by which a large quantity of carbonic acid is liberated. On the other hand, the carbonic acid produced by a manure may be too rapidly set free; and thus the plant may become, as it were, gorged with food; whilst, at a subsequent time, it is starved by the deficiency occasioned by the too great energy of the change at its commencement. In such cases, the addition of some substance (such as charcoal made from bones), which has the power of retarding decomposition, renders the operation of the manure more equable, and more correspondent with the progress of vegetation. In general, rich manures are most serviceable to plants which, being only annual, naturally grow rapidly; and those

which decompose slowly, best suit a vegetation which increases with more regularity.

190. These facts have an important influence on the operations of the cultivator; whether they be on the large scale of the Farmer, or the small one of the Gardener. No manure is more serviceable in yielding carbonic acid, than that which consists of decaying vegetable matter; and this is much more abundant than is commonly imagined. A small garden, attached to a dwelling-house, may be furnished with an ample supply of rich manure, by throwing into a pit all the refuse vegetable matter of the kitchen, and that supplied by the garden itself, in the form of weeds, dead leaves, prunings of fruit trees, &c.; these should be lightly covered with earth, and kept slightly moist, and frequently exposed to the air by being turned over with the spade.* And in a farm, there will seldom be any deficiency of similar materials, if none are wasted. Weeds, for example, should not be burned, unless they are in seed; for they may be made to afford a valuable supply of nutriment, instead of withdrawing it. A manure of this kind is to many plants more serviceable, than that furnished by animals. Some remarkable examples are on record, of the influence of it upon the growth of vines; which may be here advantageously introduced, as interesting illustrations of the foregoing principles.

191. "Nothing more," says a vine-grower on the banks of the Rhine, "is necessary for the manure of a vineyard, than the *branches which are cut from the vines themselves*. My vineyard has been manured in this way for eight years, without receiving any other kind of manure; and yet more beautiful and richly-laden vines could scarcely be pointed out. I formerly followed the method usually practised in this district; and was obliged in consequence to purchase manure to a large amount. This is now entirely saved, and my land is in excellent condition. When I see the fatiguing labour used in the manuring of vineyards—horses and men toiling up the mountains with unnecessary materials,—I feel inclined to say to all, 'Come to my

* Such a collection, however, should not be formed in the neighbourhood of a dwelling-house; as the emanations from it are injurious to health.

vineyard and see how a bountiful Creator has provided that vines should manure themselves, like the trees in a forest, and even better than they!' The foliage falls from trees in a forest, only when the leaves are withered, and they lie for years before they decay; but the branches are pruned from the vine about the end of July or the beginning of August, while still fresh and moist. If they are then cut into small pieces and mixed with the earth, they undergo putrefaction so completely, that, as I have learned from experience, at the end of four weeks not the smallest trace of them can be found."

192. The following account from a poorer vine-grower, which is to a similar purpose, is instructive, as showing of how much value a little intelligent observation may become. "For the last ten years I have been unable to place dung on my vineyard, because I am poor, and can buy none. But I was very unwilling to allow my vines to decay, as they are my only source of support in my old age; and I often walked very anxiously amongst them, without knowing what I should do. At last my necessities became greater, which made me more attentive; so I remarked that the grass was longer on some spots, where the branches of the vine fell, than on those on which there were none. So I thought upon the matter, and then said to myself: If these branches can make the grass large, strong, and green, they must also be able to make my plants grow better, and become strong and green.—I dug therefore my vineyard as deep as if I would put dung into it, and cut the branches into pieces, placing them in the holes, and covering them with earth. In a year I had the great satisfaction to see my barren vineyard become quite beautiful. This plan I continued every year, and now my vines grow splendidly, and remain the whole summer green, even in the greatest heat. All my neighbours wonder very much how my vineyard is so rich, and that I obtain so many grapes from it, and yet they all know that I have put no dung upon it for ten years."

193. Although, therefore, it is probable that all plants and trees, in full leaf, could grow without any other source of carbonic acid than the atmosphere, an additional supply encourages

that productiveness, which it is the aim of the cultivator to obtain; and it is in the choice of his materials, and the mode of their application, that his skill and judgment are shown. The science of Vegetable Physiology has been but too little connected with the arts of the Farmer and Gardener; and they have consequently been working in the dark, frequently coming, after tedious and unsuccessful trials, to conclusions which might have been drawn immediately from scientific principles. The certainty with which the mode of operation of manures upon vegetation has been now ascertained, should lead to most important improvements in practice, by which the productiveness of land may be much increased.

194. Although Carbonic acid and Water are the chief sources of nourishment to Plants, there is one element of great importance to their active growth,—namely nitrogen,—which is not contained in either of these compounds. It might be thought that, as so large a quantity of it exists in the atmosphere, no difficulty could exist, in the introduction of as great an amount of it as might be desirable, into the Vegetable system. But it would seem that none of the elements, of which that system is composed, can be introduced into it in a *simple* form. Thus we have seen that the carbon is derived from carbonic acid, and the oxygen and hydrogen from water: and it is found that plants rather increase than diminish the quantity of nitrogen in the atmosphere. Nitrogen is introduced in the form of *ammonia*, the pungent gas which gives strength to hartshorn, smelling-salts, &c., and which is liberated by the decomposition of almost all Animal substances, in which nitrogen very largely exists. A great quantity of this gas is thus being constantly set free and diffused through the atmosphere; but still it forms so small a proportion of the whole, that it cannot be shown to exist in the air, otherwise than in an indirect manner. Ammonia is very readily absorbed by water; and thus the rain and dew, in descending through the atmosphere, become impregnated with it, although in very small amount. This ingredient can be proved to exist in rain-water; and thus its presence in the atmosphere becomes certain.

195. The quantity of Ammonia which is thus supplied to plants, appears sufficient for their ordinary growth. If, however, plants be set in powdered charcoal, sheltered from rain or dew, and watered with distilled water (which contains no ammonia), they do not flourish as they have been stated otherwise to do, but soon become stunted in their growth. This fact proves the great importance of the small amount of nitrogen thus introduced. There are many plants, however, to which a much greater supply of ammonia is necessary, on account of the large proportion of nitrogen, which enters into some portions of their structure; and these can only be cultivated to advantage, when surrounded by additional sources of this material, such as are afforded by decaying *animal* matter of various kinds. For example, corn-grains include a large quantity of starch, which contains but little nitrogen, with a certain amount of gluten, of which nitrogen forms a large proportion; the latter is the more nutritious ingredient of the two; and it should be the object of the farmer to make the proportion of it as great as possible. This may be effectually accomplished, by such Animal manures, as yield a large supply of ammonia. Thus, whilst corn grown in common vegetable mould contains about 66 parts of starch in every hundred, and only 9½ of gluten,—that which had been manured with blood or urine was found to contain 45 parts of starch, and 35 of gluten. It is by the use of a rich animal manure termed *guano*, that the barren soil on the coast of Peru is rendered fertile; this guano is collected from several islands in the South Sea, on the surface of which it forms a layer of several feet in thickness; and it consists of the excrements of innumerable sea-fowl, which resort there during the breeding season. It is sufficient to add a small quantity of guano to a soil, which consists only of sand and clay, and which previously contained not a particle of organic matter, in order to produce the richest crop of maize.

196. Many kinds of soil have the power of absorbing ammonia like carbonic acid, from the atmosphere; and thus add to the supplies which the plant obtains by its roots, so as to diminish the necessity for animal manure. Of this kind is gypsum,

the utility of which has long been known, although the cause of its beneficial influence was not suspected. Gypsum powerfully attracts ammonia from the atmosphere, and yields it again to water which may soak through it; so that as much ammonia, as would supply the proportion of nitrogen to 100lbs. of grass, is yielded by little more than 4lbs. of gypsum. The advantage of manuring fields with burned clay, and the fertility of soils containing iron, are to be referred to the same cause. Burned clay has, like gypsum, the power of fixing ammonia from the atmosphere, and of easily yielding it to water; and minerals containing oxide of iron do the same, when separated into fine particles. Powdered charcoal possesses a similar action, and, indeed, surpasses all other substances in its power of condensing ammonia within its pores, absorbing 90 times its volume of this gas. Decayed wood approaches very nearly to charcoal in this power; and vegetable mould, which principally consists of wood in a more advanced state of decay, retains it in a very important degree; so that we perceive its influence on vegetation, to be by no means confined to the supply of water and carbonic acid.

197. On this account, vegetable mould is alone amply sufficient for the cultivation of all Plants, which contain but an average proportion of nitrogen; but Corn can only be grown to the greatest advantage, when the land is well manured with those substances, which contain the largest proportion of ammonia. This is yielded in the greatest abundance, by the excrements, both fluid and solid, of Animals, and particularly of Man; and in China, where, from the immense population, it is necessary to make the most of every foot of ground, the greatest care is taken to preserve these; and extraordinary fertility is the result. A similar practice prevails on some parts of the Continent of Europe; and it is less successful, only because the mode of collecting the materials allows of the escape of a large proportion of the ammonia, before the manure is used.

198. By a judicious system of management, large towns may thus be rendered most important means of increasing the fertility of a country, and therefore of contributing to the supply of wholesome food; instead of bringing together, as at present, so many causes of misery and unhealthfulness.

199. The sources of what may be regarded as the essential ingredients of the food of Plants, having now been fully considered, (the more fully on account of the practical importance of the subject,) we shall inquire into the influence of certain other materials, which particular kinds require for their healthful growth; an increased supply of which tends greatly to their productiveness, and the influence of which ought, therefore, to be fully considered, in the tempering of soils, or the application of manures. These materials consist of solid particles of various kinds, which are contained in the earthy portion of the soil, and which, being dissolved in the water, are taken up by the roots. Of these, some are imbibed by almost all plants alike; whilst others are retained only by particular kinds, so that they are either not taken up at all by plants of other kinds, or are secreted again into the soil, not being deposited in their tissues.

200. There is considerable variety in this respect, among the different tribes of Plants; each seeming to grow most advantageously, when supplied with a certain kind of mineral matter, but being capable of taking up other forms in place of it, if it should be deficient. Thus the Rhododendron, like most other plants, deposits in its leaves and stem a large quantity of calcareous matter (lime combined with an acid, usually the carbonic,) when freely supplied with it. When grown in a calcareous soil, the ashes of its leaves have been found to contain $43\frac{1}{4}$ parts in 100 of carbonate of lime, and only $\frac{3}{4}$ of silex or flinty matter; the ashes of the stem of the same plant contained 39 of calcareous earth, and $\frac{1}{2}$ of silex. But when grown in a soil in which silex predominated, the leaves of a similar plant contained $16\frac{3}{4}$ per cent. of earthy matter, and 2 parts of silex; whilst the stem contained 29 parts of calcareous earth, and 19 of silex.

201. It is curious to observe that, whilst calcareous matter seems principally deposited in the softer tissues, silex is found much more abundantly in the stem. This is especially the case in the Grasses, nearly all of which require for their healthy growth, a large proportion of silex; and this substance it is, which, being deposited in the slender tissue of the hollow stem, imparts to it a strength, that seems disproportionate to the quantity of matter it contains. The silex may be melted by

means of the blowpipe (potash being also present in the tissues), into a bead of nearly the same appearance as glass; and the following curious instance shows the same effect upon a large scale. A melted mass of glassy substance was found on a meadow between Mannheim and Heidelberg in Germany, after a thunder-storm. It was at first supposed to be a meteor; but, when chemically examined, it proved to consist of silex combined with potash, in the form in which it exists in grasses; and, upon further inquiry it was ascertained, that a stack of hay had stood upon the spot, of which nothing remained but the ashes, the whole having been ignited by the lightning.

202. Now the various substances which are thus required by plants for their healthy growth, are generally contained in the soil in sufficient amount, to supply the majority of Plants with the necessary material; and some, when exhausted from the soil, may be supplied again from the water of the district, in which they are dissolved. It is partly by thus renewing what has been withdrawn, that the irrigation or flooding of meadows with water, is very serviceable. Even where this water is of ordinary purity, containing scarcely any organic matter, and but very little of mineral ingredients, the irrigation of meadows is very serviceable in improving their productiveness. From three to five perfect crops of grass have thus been obtained every year, by covering the fields with river-water, which is conducted over it in spring by numerous small canals; so that the quantity produced in all was more than four times that, which would have been obtained from one not so watered. In the neighbourhood of Edinburgh, the stream which conveys the fluids, collected from the sewers of the town into the sea, has been diverted, so as to cover much of the low meadow land that surrounds the town on three sides; and the large quantity of organic as well as mineral matter, which the fluid contains, is so beneficial to the growth of grass, that the previous produce has been eight or ten times multiplied. This proceeding is very injurious, however, to the health of the town; since the offensiveness of the putrefying matter is very much increased, by being diffused through a large quantity of water.

203. The soil may be artificially supplied with the mineral substances required by different kinds of Plants, as well as with those which yield carbonic acid or ammonia; and the cultivator is frequently obliged to do this (though in general without understanding the true benefit of the operation), especially when he has forced the growth in other ways. Thus if a meadow be manured only with gypsum (the use of which has been already mentioned), the crops of grass will be at first greatly increased, but will afterwards diminish; for the potash which the soil contained, is soon exhausted by the rapid growth of the grass, and its further increase is checked. But if the meadow be strewed from time to time with wood-ashes, which contain potash, the grass will thrive as luxuriantly as before. A harvest of grain may be obtained at long intervals on a sandy heath, by strewing it with the ashes of the heath-plants which grow on it, and which gradually collect the alkalies that are conveyed to them by water.

204. It seems a remarkable fact, that those plants of the grass tribe, the seeds of which furnish food for Man, follow him like the domestic animals. The reason is, that none of the corn plants can bear seeds that will yield a large quantity of flour, without a good supply of phosphate of magnesia and ammonia. Hence these plants grow only in a soil, which contains these ingredients, in addition to the silex and potash already mentioned; and no soil is richer in them, than those where men and animals dwell together; since these substances are largely contained in the animal body, and are set free in their excretions during life, and by their general decay after death. Again, this fact explains why bone-earth is a most valuable manure to corn-fields; since it consists almost entirely of these ingredients. The knowledge of it will also guide us in selecting the *kind* of wood, of which the ashes will be most valuable; for whilst those of the oak contain but a minute proportion of the phosphate, and those of the pine a quantity not exceeding the sixth part of their weight, those of the beech yield the fifth part; and thus with every 100 lbs. of the ashes of the beech, we supply a field, with enough of these ingredients, to serve for the growth of more than 15,000 lbs. of corn.

205. It should be the object of the agriculturist, therefore, to ascertain the chemical character of the earthy portion of the soil which he cultivates, and to manure it with such substances, as he finds will supply the deficiency, for the particular plants which he wishes to grow. There are some soils, which contain all the ingredients required for almost any kind of vegetation; and, when these cease to be productive, all that is necessary, is to allow them to lie fallow during a season or two. The atmosphere then acts upon the mineral particles, and causes that more complete separation amongst them, which is necessary to prepare them for being dissolved in water, and for taking up by the roots of the plant. In this manner some soils prove extremely fertile, which scarcely contain a particle of vegetable mould, and have received very little animal manure. Thus the land in the neighbourhood of Mount Vesuvius contains clayey earths, with chalk and sand, mixed in such a proportion, as to give free access to air and moisture. This soil is produced by the slow decomposition and separation,—through the agency of the air, and of the roots of a Cactus that act in the manner formerly described (§. 108),—of the masses of lava which have at different times issued from the volcano, and which contain a great admixture of mineral matters, without a particle of vegetable mould. Now corn has been grown on this land for thousands of years, with scarcely any manure;—the method adopted being simply this. A field is sown once every three years only; and is in the intervals allowed to serve as a sparing pasture for cattle, which feed on the weeds that spontaneously spring up. But the influence of the weather sets free an additional quantity of the mineral ingredients, which the corn requires; the amount of nutriment contained in the seed, is sufficient for the development of the young plants; and the soil is of a kind extremely favourable to their subsequent growth.

206. On the other hand, the very fertile land, which was found by the first settlers in Virginia, has been exhausted by a contrary proceeding. Harvests of wheat and tobacco were obtained for a century, from one and the same field, without the aid of manure; but now whole districts are converted into

unfruitful pasture-land, which, without manure, produces neither wheat nor tobacco. From every acre of this land, there must have been removed in the space of one hundred years at least 1200 lbs. of alkalies, in leaves, grain, and straw; it became unfruitful, therefore, because it was deprived of every particle of alkali, that had been reduced to a state capable of being dissolved; and it would require to lie entirely fallow for a great length of time, to regain its fertility. Almost all the cultivated ground in Europe is somewhat in the same condition. That of many of the West India islands has been also exhausted, by the avarice of its former possessors; who have left it in a state, which renders the cultivation of Sugar much less profitable than formerly, since the Canes cannot be grown without a large quantity of manure. If the ashes of the Canes,—which, after the juice has been pressed from them, are burned, to heat the pans for boiling down the fluid,—were to be spread over the fields, the productiveness of the land would probably be much increased: and it would be much preferable to give back to the soil the whole solid matter of the Canes, which remains after the juice has been pressed out from them, together with the leaves, &c. that are stripped from them during their growth. Thus *all* the constituents of the tissues of the plant, which have been withdrawn from the soil, would be restored to it; and as the Canes would thus be made to manure themselves (like the Vines already mentioned, §§. 191, 192), the soil would thus be enabled to afford successive crops, without the aid of any other manure. The sugar would then be the only substance withdrawn from it; and this is probably formed, chiefly, if not entirely, at the expense of carbon and water derived from the atmosphere.

207. It is not always necessary, however, that a field should lie fallow, in order to render it capable of producing some particular kind of crop, the materials of which had been exhausted; for, if it be sown with some vegetable of an entirely different kind, a profitable crop of this may be raised, whilst the land is renewing itself for the other. The power of doing this depends upon the nature of the ingredient which is deficient. It has been formerly shown, that it is not the vegetable portion of the soil,

which is exhausted by the continued growth of any race of plants in the same spot, this being usually rather increased than diminished; and therefore any plants, which require no other nutriment than this, may be made to grow in a soil, which wheat, or some other plant that takes up a large portion of some particular kind of mineral matter, had completely exhausted. Such is the case, for example, with many of the *Leguminous* plants (the tribe including the Pea, Bean, Clover, and other similar vegetables), which absorb so little mineral matter, that they may be grown between two crops of corn, with nearly the same advantage for the latter, as if the land had lain fallow between. Hence these are called fallow crops. On the other hand, the injurious properties of many weeds that are apt to show themselves in corn-fields, result from their imbibing a large quantity of the same ingredients, as those which the corn requires; so that, in proportion to the vigour of their growth, that of the corn must decrease. Hence it not only conduces to the neatness in the appearance of a corn-field, but also to its productiveness, to keep it free from weeds.

208. Now the principle that a succession of *different* crops may be grown, where *one* could not be repeated without occasional intervals, has gradually superseded the old system of allowing the land to lie for a season, out of every three or four, entirely unproductive; so that the quantity of vegetable substances, nutritious either to man or beast, which is now raised from a given quantity of land, is much greater than formerly. This principle has been fully established by experience; but it is still acted on to a very limited degree, because its conditions are not yet fully understood. If there were nothing else to be considered, than the kind of mineral substance which each plant draws from the soil, it would not be difficult to say, what crops might succeed each other most advantageously, since it would be only necessary to find out the mineral ingredients which each requires, and to make those succeed each other, which draw least of the same. But there is another very important condition to be attended to.

209. Plants, as already stated (§. 119), not only draw

various substances from the soil, but impart to it a portion of the juices, which they have formed within themselves. A well-marked instance of this is the Oak; which so completely impregnates the soil around its roots with *tannin* (the substance which gives to oak-bark its peculiar power of converting animal skin into leather), that few trees will grow in the spot from which it has been rooted up; since this agent, even when a very minute quantity of it is dissolved in water, produces an effect like *tanning* upon the delicate tissue of the spongioles, and destroys their peculiar properties. It is probable that every species of forest-tree produces a similar effect; since it is well known that, when a wood composed of one kind has been cleared by the hatchet or by fire, the new growth which soon springs up, is not of the same, but of a different species. Again, some of the plants which are known as the rankest weeds, secrete from their roots substances equally injurious to plants around them; thus the Poppy tribe impregnates the soil around with a substance analogous to Opium, which is easily shown by experiments, to have as injurious an effect upon Plants, as an overdose of this powerful medicine has upon Animals; and the Spurge tribe exudes an acrid resinous matter.

210. The Excretions of all Plants seem injurious to themselves, as well as to others of the same species grown in the same spot; and in many instances, as in those just quoted, they are injurious to plants of other tribes also. But there are many instances, in which they are absolutely beneficial to plants of distinct tribes. Thus most of the Leguminous tribe exude from their roots a matter analogous to gum; as may be easily shown, by growing a pea or bean in water, which soon becomes turbid; and this product is beneficial to plants of almost every other tribe. Hence, therefore, the benefit which the farmer derives, from taking off a crop of beans between two crops of corn, is not restricted to the value of the former; since the succeeding crop of corn is absolutely improved by this proceeding. And, on the other hand, the exhaustion of the soil by rank-growing weeds is not their only evil; since they impart to it some of their own injurious properties.

211. Now, by following out this system, and ascertaining what Plants form the most abundant, and at the same time the most nutritious excretions, and what are the others which are most benefited by these,—keeping in view, also, the nature of the mineral ingredients they may respectively require, the agriculturist may hereafter be able to dispense almost entirely with artificial manure, as he has already done with the fallowing system;—for he will only have to adapt his rotation to the particular soil, and then the excretions of one plant will serve as a manure to the other. Among the most useful for this purpose may be mentioned Lucern, which is remarkable for the extensive ramification of its roots, and the strong development of its leaves, and which requires but a small proportion of inorganic matter. This plant produces an abundant secretion from its roots, which, in the course of several years adds considerably to the quantity of vegetable matter in the soil, whilst its leaves serve as nutritious food for cattle.

212. The subject of the foregoing Chapter has been treated in more detail than may seem consistent with the plan of this work; because it is, of all departments of Vegetable Physiology, the one of most importance to the well-being of Man. It can scarcely be doubted that, by improvements in the art of Agriculture, the quantity of food for man and beast produced in this country, and the amount of those valuable articles which are cultivated in the various colonies of Great Britain, may be greatly increased. But these improvements cannot be carried into advantageous operation, until correct ideas on the subject have been generally diffused among those, who are concerned in the work; for, unless the *principles* on which they are founded are properly understood, it is more than probable, that loss instead of gain will result, from the attempt to introduce them.

213. These principles may be thus recapitulated.

I. The soil should be of such a character as to afford a steady supply of *moisture* to the roots, and to allow the air to penetrate it freely; if it does not possess these requisites, it should be improved by tempering (§. 176—8).

II. In order to produce that luxuriant growth of plants which

the agriculturist desires, the soil should afford a supply of *carbonic acid* to the roots, either by the decomposition of vegetable mould, or by absorbing the gas from the atmosphere. Its fertility may be increased by the addition of vegetable substances disposed to decay; or by mixing it with charcoal, gypsum, or some other substance, which possesses in a high degree the property of absorbing carbonic acid from the atmosphere (§. 179—193).

III. In order to effect the same object, the soil should be capable of affording a supply of *ammonia* to the roots, either by the decomposition of animal matter contained in it, or by attracting that gas from the atmosphere. The proper supply of this important article of food may be secured, either by the employment of some animal manure which liberates it freely, or by the admixture of some substance (such as gypsum or charcoal) which absorbs it rapidly from the atmosphere. The first method is most desirable, when the vegetable substances, which it is required to obtain in the greatest quantity, contain much ammonia; as do the seeds of corn (§. 194—8).

IV. In order to promote the luxuriant growth of any tribe of plants, the soil should be supplied with those mineral ingredients, which its tissues naturally contain. If these are originally deficient, they must be added; if they are contained in the soil, but have been for a time exhausted, the land should be allowed to lie fallow, until the action of the weather has further separated the mineral particles (§. 199—206).

V. The soil may be improved nearly as much by a crop of a different kind, as by lying fallow; provided *that* crop do not exhaust it of the same mineral ingredient with the one it replaces, and furnish excretions which are beneficial to it (§. 207—211).

CHAPTER VII.

OF THE STRUCTURE OF LEAVES.

214. The fluid which is so abundantly taken up by the Roots of plants, and which is conveyed upwards along the interior of the Stem, is very unfit for the nourishment of the structure, and for the supply of the growing parts, until it has been exposed to the influence of the air, by which great changes are effected in its properties. Now this object has to be attained in Animals, as well as in Plants; and we observe two modes of effecting it. In some Animals, the blood is sent into very delicate external prolongations of the skin, termed *gills;* through the thin membrane of which, it may receive the required influence. And, although we usually see an apparatus of this kind, existing only in animals which inhabit the water (the air diffused through which is really that which acts on the blood), yet it is seen in some air-breathing animals also. The usual mode, however, in which the blood is exposed to the influence of the atmosphere, in animals living on land, is by the introduction of air into cavities termed *lungs* within the body, constituting the process known as *respiration* or *breathing*; but this requires a series of movements, for the constant exchange of the air so introduced; in order that the portions rendered unfit for further use, by the changes that take place in it, may be expelled, and a fresh supply admitted. A little consideration will show, that to have introduced water in a similar manner, into the interior of the bodies of those animals which inhabit it, would require an immense amount of force, since water is so much less easily moved than air; whilst, on the other hand, to have furnished air-breathing animals with external gills or other similar appendages, would have exposed

them to great risk of injury, would have impeded their rapid movements, and would have been attended with many inconveniences.

215. Now in Vegetables, the same object is to be attained; but under different conditions. The nutritious fluid of the Plant, like the blood of animals, needs to be exposed to the influence of the air, to preserve its power of maintaining life; and this cannot be effected, either by the underground roots, or by the hard woody stems and branches, which expose so small an amount of surface to the atmosphere. Nor can this be effected, by the introduction of air into internal cavities in these parts; since this would require a continued series of movements, as in air-breathing-animals, which the Plant has no means of performing. Again, as the Plant is rooted in the earth, and is not adapted to move through the atmosphere, there is no reason why its surface should not be spread out to any extent, for the purpose of exposing the sap to the influence of the air; just as the blood is exposed in the gills of fishes and other aquatic animals, to the small quantity of it contained in the water they inhabit. Further, a very essential condition of the changes, which the sap undergoes by coming into contact with air, is the influence of *light;* without which they would be very imperfectly performed.

216. This general view of what is required from the *Leaves*, will suffice to show, how beautifully their structure and situation are adapted to the offices they have to perform. The leaf may be said to consist essentially, of an extension of the skin or cuticle of the Plant, into a flat expanded surface; which is supported by a skeleton, prolonged from the wood of the stem or branch. If any leaf be but cursorily examined, it will be seen that from each surface a sort of skin may be torn, which may sometimes be stripped off very cleanly from the tissue beneath;—the space between these surfaces being occupied by soft green tissue, which the naked eye can often perceive to consist of separate particles loosely united, and which is seen with the magnifying-glass to be composed of distinct cells, usually more closely packed together near the upper surface than near the lower, where there are many cavities or interspaces among them.

217. The cuticle of the leaves is furnished more abundantly than those of any other parts, with *stomata* (§. 91), by which watery vapour and gases can pass out, and air can enter; but these are chiefly, and often entirely, confined to the lower surface. The woody skeleton of the leaf forms what is commonly known as the *midrib*, and the *veins* proceeding from it. These *veins* or *nerves* (as they are commonly termed) must not be confounded with similar parts in animals, since they do not in the least resemble them. They are principally composed of woody fibre, and of spiral vessels and ducts; and they proceed from the neighbouring stem or branch, constituting the greater part of the *footstalk* or *petiole* of the leaf, from which they afterwards spread out.

218. This general account of the structure of the leaves of Flowering-plants, will suffice to enable us to compare them with the corresponding parts in Cryptogamia. It also enables us to see how beautifully they are adapted,—by the immense amount of surface they present,—by its thinness and delicacy,—by its numerous apertures,—and by its expansion to the light of day, for the purpose they have to perform;—the exposure of the crude sap to the air and sun, under the influence of which, it is elaborated or digested, so as to become a highly-nutritious fluid.

219. There are few Flowering-plants, in which the stem and branches are not, at some part of the year, clothed with these beautiful appendages; and the exceptions are chiefly in those forms—unknown as natives of temperate climates, but common in tropical regions,—in which the stem itself is so altered in structure, as to be able to perform the functions of leaves. Most of these are included under the designation of *Cactus* or *Prickly-Pear* tribe. Their stems, instead of being firm and woody, are comparatively soft and fleshy; their substance is moist, and composed almost entirely of cellular tissue; their surfaces are green, and covered with a distinct cuticle, which is furnished with stomata; and their form is often flattened, so as to expose, like leaves, a large surface to the air. It is interesting to observe, how completely the deficiency of one organ is here supplied by

a modification of another. In almost all the plants of this tribe, there are tufts of prickles arising from regular points on the surface of the stem; and to these, the common designation of the tribe is owing. It will be hereafter shown, that these prickles are the *rudiments* of leaves; and that, under circumstances different from those in which the plant naturally grows, minute leaves will arise from these very points.

220. A conformation somewhat similar may be observed in some plants of our own country; thus in the common *Butchers' Broom* (*Ruscus aculeatus*), the branches are flattened into a leaf-like form, and the flowers arise from the middle of their surface. In another foreign genus, *Xylophylla*, they are placed around the edges of similar organs.

FIG. 59.—*a*, LEAF-LIKE BRANCHES OF BUTCHER'S BROOM, bearing flowers in their centre; *b*, Xylophylla.

221. There are, however, some flowering-plants of temperate climates, which are destitute not only of leaves, but of leaf-like surfaces. These grow by imbibing the juices of other more perfect plants; just as parasitic animals obtain their food, by sucking the blood of others. And as the juices that afford them support, have already been elaborated or digested by the plant from which they draw them, they have no need of leaves or any similar apparatus for the purpose. Of this kind are the *Orobanche*, or *broom-rape*, and the *Cuscuta*, or *dodder*. Their branching roots are furnished with suckers, by which they affix themselves on the bark of the plants, round which they cling, and through which they imbibe their juices. (See §§. 343, 344).

222. Although there are few instances, then, in which leaves are absent in Flowering-plants, they are comparatively seldom found in Cryptogamia. In FERNS we always meet with them; and their general structure is much the same as that, which will be described as characteristic of leaves in general. But, in

addition to their other functions, the leaves of Ferns very commonly bear the fructification upon their under surface; and hence the name *frond* has been given to them, for the purpose of distinguishing them from the leaves of the Phanerogamia, in which they never bear a part in the production of seed. In some of the Ferns, as the *Osmunda regalis*, or Flowering-Fern (as it has been incorrectly called), a handsome and well-known species common in some parts of England, the fructification is only borne on the edges of particular leaves, which are much less expanded than the rest; these are, therefore, called *fertile fronds;* whilst the other leaves, which here altogether resemble those of Flowering-plants in function, are called *sterile fronds*. In MOSSES, we observe a large number of minute and delicate leaflets, having no concern in the fructification, which is entirely distinct; but they have not those peculiarities of structure which distinguish the leaves of higher plants, being destitute of a woody skeleton and of stomata; and they seem to have a greater mixture of function, since they not unfrequently send out root-fibres from their under surfaces, for the purpose of absorption.

223. We observe in the lower and simpler tribes, as has been heretofore shown, a much greater blending of different functions, than in the higher; which last possess a special organ for each, and in which they are consequently performed in a more energetic manner. Thus, when we descend below the Mosses, we find no distinct leaves;—they become, as it were, blended with the general surface; and all their functions are performed (as in the *Cactus* tribe) by this. Such, it will be remembered, is the case in the Liverworts (§. 32); and also in the LICHENS and ALGÆ, in many of which, however, we notice a flat expanded surface, by which the functions of leaves may be in some degree performed. This expanded surface is often of great extent in the Algæ, and possesses a very leaf-like aspect; but, as already stated, it does not perform the functions of leaves alone, but is everywhere equally adapted for absorbing the fluid that constitutes its nourishment, and in many instances contains the fructification also imbedded in its substance (§. 41).

224. The case is different, however, in regard to the FUNGI. These plants derive their nourishment from matter, which has already been in a state of organisation; and the condition in which they receive it is such, that it does not require to be elaborated by exposure to the atmosphere, as it does in all other but the parasitic plants already mentioned, which much resemble the Fungi in habit. Accordingly the Fungi, the whole energy of whose vegetation seems to be concentrated upon the propagation of the race, do not possess anything analogous to leaves; and seldom exhibit even such an expanded surface, as may be considered to replace them. It is very rare, too, that this surface is *green;* and, as will be hereafter shown (§. 286), this green colour in leaves is due to certain changes, which, from the condition of the growth just mentioned, the Fungi do not need to perform.

225. We now return to the leaves of Flowering plants; and shall trace in more detail their regular structure, the chief varieties of this, and the functions which they are destined to perform. And in the first place we shall consider their external aspect.

226. The leaf is usually borne upon a *petiole* or foot-stalk; which connects it with the stem; and it is at the bottom of the petiole, that the separation from the stem takes place, when the leaf falls off. By this it may be known what is really a single leaf, and what is a collection of separate leaves. Not unfrequently a leaf is very compound in its structure, consisting of a number of distinct leaflets, which might be regarded as so many leaves. But if these leaflets all proceed from one foot-stalk, and this drops off altogether at the accustomed period, they are to be considered as only the subordinate parts of a single leaf. Many such instances might be enumerated; but it will suffice at present to refer to the Ferns (§. 23), in which what appears to be the stem is really but a leaf-stalk; and what seem to be leaves are only leaflets proceeding from it, and forming part of one large leaf.

227. There is not always such a definite distinction between the flat expanded blade and the round and slender petiole, as,

from what we observe in common plants, we might suppose to be the case. The petiole is sometimes expanded into a leafy surface, and may even perform all the functions of the true leaves, when the latter are deficient. Thus in a British aquatic plant, known by the name of *Arrow-head* (technically *Sagittaria sagittifolia*) which is common in running streams, we observe what appear to be two kinds of leaves; some elevated above the surface, and formed like the head of an arrow (whence the name of the plant); and others flattened, of equal breadth throughout (technically termed ligulate or strap-shaped), and not appearing above the water. These last are in reality the flattened petioles, which perform the functions of leaves, as long as they remain under water; but as soon as any of them have strength to elevate their summits above its surface, true leaves are developed from them, and the petiole then contracts into a rounded form.

FIG. 60.—SAGITTARIA SAGITTIFOLIA, OR ARROW-HEAD; showing expanded petioles beneath the water, and true leaves above.

228. A corresponding structure is exhibited by some of the Acacias of New Holland; which are sometimes so completely destitute of true leaves, as to be termed "leafless." When this is the case, the petioles are flattened and expanded, and present a leaf-like surface, which is adapted to perform the functions of the true leaves; from these they differ, however, in having the two surfaces alike, and in their expansion being vertical, instead of horizontal. The true leaves (which, like those of other Acacias, are very compound in their character, see Fig. 61,) are only to be found in young plants, or in old ones which have been freely pruned; and it is not uncommon to find many degrees of development, intermediate between those which exhibit the fully expanded leaf with its narrow and cylindrical petiole, and those which have no vestige of the blade, and present nothing but

the leafy foot-stalk. In all these, the amount of expansion of the petiole bears a precisely inverse proportion to that of the

FIG. 61.—BRANCH OF NEW HOLLAND ACACIA.

leaf; the former replacing the latter, when it is unfit to perform its functions.

229. The *blade* of the leaf is composed of the expanded veins or nerves proceeding from the petiole, the interstices between which are filled up with cellular tissue, and the whole covered with cuticle. The mode in which these veins are distributed is very characteristic of the principal divisions of the vegetable kingdom. Thus, in the CRYPTOGAMIA, wherever true woody veins

exist in the leaves (which is scarcely the case in any but the Ferns,) they are seen to divide and subdivide,—each usually bifurcating, or splitting into two branches like the prongs of a fork, at intervals;—and in general, these subdivisions do not unite again. Hence, as regards their leaves, the Cryptogamia may be characterised as *forked-veined.*

230. In the group of Endogens it may be observed, that the veins run in a nearly straight direction, and almost parallel to each other; and that they have but little connection, by the interlacement of their minor subdivisions. The arrangement of these veins, however, differs according to the general form of the leaf. Thus, in the long narrow leaves of the Grasses, and of other Endogens, such as the Lily, Iris, &c., the foot-stalk is not

FIG. 62.—ENDOGENOUS LEAF.

continued along the leaf as a great central vein or *midrib*, but divides at once into several veins, which run along side by side, from one end of the leaf to the other; and as there is very little connection between these different veins, the leaf may be readily and very straightly torn, from one end to the other. In other cases, however, the leaf is broader, and the parallel veins are sent off from a large central midrib, running in the direction of the breadth of the leaf. As these, too, are but little connected with each other, it is easy to tear one of these expanded leaves into a number of narrow ribands, which will then hang from the midrib; and something resembling a compound leaf will thus be produced. As each of these ribands will have its own vein

uniting it with the midrib, and is in its natural state scarcely connected with the surrounding parts, except by the cuticle which envelopes the whole, the leaf will perform its functions nearly as well when thus subdivided, as when entire.

231. It is curious that such a separation should sometimes take place under the influence of natural causes. The Banana and Plantain of tropical climates, have leaves of this kind; and when they grow in situations, in which they are much exposed to the wind, its action splits them up in this manner, from which they do not appear to suffer. These plants are sometimes grown in hot-houses in England; and then, being completely sheltered, the expansion of their leaves is preserved entire, which seldom happens in their native localities.—In whichever direction the veins are arranged, the general character of the leaf is the same; and hence the leaves of Endogens are spoken of as *parallel-veined*, by which character they are distinguished, with but few exceptions, from those of the Cryptogamia on one hand, and, as will presently appear, from those of Exogens on the other.

232. The form and mode of subdivision of the system of veins in *Exogens*, are extremely irregular; but there is a character common to all, by which the leaves of this group may be distinguished, without much difficulty, from those of the

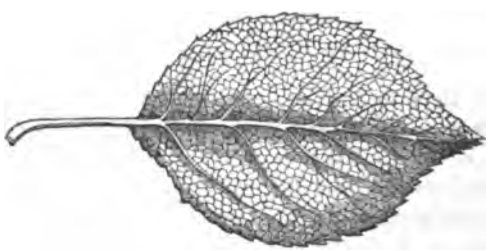

FIG. 63.—EXOGENOUS LEAF.

others. There is usually a midrib, or prolongation of the foot-stalk along the centre of the leaf, from which the smaller veins arise; but sometimes the petiole subdivides at once into several subordinate veins, which run from one extremity of the leaf to the other, nearly parallel with each other, as in Endogens. But

the secondary veins of Exogens, however they may be disposed, always give off a vast number of minute branches, which ramify and unite with each other, so as to form a complete network; and thus it is, that the leaf of an Exogen can seldom be torn with any regular edge. From this character, the Exogens may be described by their leaves, as *reticulated-veined;*—the veins forming a *reticulum*, or minute net-work.

233. It is in these that we can make the most beautiful skeletons, by removing the soft fleshy portion of the leaves, and preserving only the woody structure. Such skeletons may often be found in the autumn, when the fallen leaves have been exposed to the influence of moisture for some time; and with slight care, they may be made to exhibit a very beautiful appearance. They may easily be prepared, by soaking in water a leaf possessed of firm texture, until its softer portion be in a state of decay; if then the latter be washed away, by carefully directing a small stream of water against it, the skeleton will be left. Not only do leaves contain such a skeleton; but the leafy parts of flowers; and even the *skins* of such soft fruits as the cherry.

234. Now, with the same distribution of the veins of the leaf, many curious varieties of structure may be produced, by a difference in the degree in which the space between them is filled up. One of the simplest of these, is where holes are left in the blade of the leaf, in consequence of a deficiency of the fleshy portion. Some plants are particularly liable to this irregularity; which does not exist, however, where they are well supplied with nourishment. A similar, but much more curious variety exists in an aquatic plant of Madagascar; in which the fleshy cellular tissue, or *parenchyma*, is so little developed between the veins, that the living leaf much resembles in its form one of the skeletons just described.

235. It is by no means uncommon, to see the edges of leaves more or less deeply indented, according to the amount of nutriment which the plant is receiving; the distribution of the veins, and the general outline of the leaf, remaining the same through-

out. Thus the *Cochlearia*, or Horse-radish, has the edges of its leaves nearly smooth, when growing in a sufficiently rich soil; but if starved, the blade will be divided into separate strips like the teeth of a comb, from the deficiency of flesh to fill up the spaces between the veins. In the accompanying figure are represented the outlines of different leaves, having the same general distribution of the veins, but a different proportion of the fleshy substances between them.

FIG. 64.—DIFFERENT FORMS OF LEAVES HAVING THE SAME VENATION; *a*, Water Crowfoot; *b*, Jatropha; *c*, Passion-flower; *d*, Sterculia platanifolia; *f*, Dichondra; *g*, Asarabacca.

236. In some plants, in which the framework of the leaves is very strong, the ends of this project from the edges of the leaf, when the latter is stunted in its development, forming sharp prickles. This is the case in the Holly; the prickles on the leaves of which will be at once seen, if examined, to be simply the dried and projecting terminations of the veins. On looking at any full-grown Holly, considerable variety will be noticed in the degree, in which the leaves have this prickly character; and in general it is seen, that the lower ones are the most stunted and rough, whilst the upper ones have the parenchyma of the leaf so much developed, as to include these extremities, and thus to render the edges of the leaf quite smooth. Sometimes it has been observed that a Holly, growing in a very luxuriant soil, has had all its leaves in this manner metamorphosed, so as entirely to lose the peculiar aspect of the tree. This is one of

the modes in which the repulsive character of some plants is softened down by cultivation. In the *Cactus* tribe, it would seem as if all the nourishment, which would naturally form leaves, is bestowed upon the stems themselves; and thus the tufts of prickles already noticed (§. 219) are the only indications of their place. These prickles are the woody veins; which are sometimes seen, in specimens grown in hot-houses in this country, to be converted into true though very minute leaves; in consequence, probably, of the greater supply of nourishment they receive under such circumstances, than in the dry and sterile situations they frequent in their native climes.

237. The division of leaves into leaflets may be regarded as taking place upon the same general principle. When a single series of leaflets arises from the midrib, the leaf is said to be *pinnate*, or winged. But sometimes, instead of leaflets arising

FIG. 65.—PINNATE LEAVES.

from the midrib, we find secondary veins, from which, as from smaller midribs, secondary leaflets arise. Such are called *bi-pinnate* leaves. The division may go yet further; and the

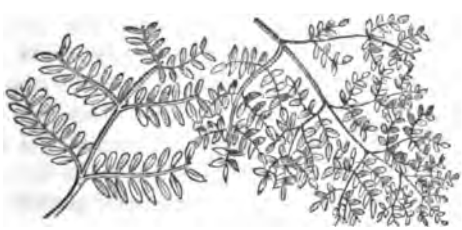

FIG. 66.—BI-PINNATE AND TRI-PINNATE LEAVES.

secondary veins may give off their branches before any leafy

parts appear on them, and these are of course much smaller and at the same time more numerous. A leaf in which this is the case is termed *tri-pinnate*. Such forms are generally peculiar to different kinds of plants; but there are some in which we find them strangely intermixed, so as to display their real origin and character.

238. Such an example is afforded by the *Gleditsia* or Honey-locust tree of North America, known to English gardeners by the name of the three-thorned Acacia. As in other Acacias, the leaves are compound; but the division often proceeds to such different degrees, in different parts of the same leaf, that it is difficult to say, whether it is to be considered *pinnate*, *bi-pinnate*, or *tri-pinnate*. Of such a leaf, in the accompanying figure, the central stem is the midrib; and from it proceed the secondary veins on each side. The highest pair of these, bears on one side a leaflet, which shows indentations marking a tendency to subdivision; and, on the other side, a series of secondary leaflets, formed by the complete subdivision of the first. The second pair of veins bears on one side a series of secondary leaflets nearly similar; but two of these are seen to have again subdivided into more minute leaflets: the distribution of the veins in which, however, precisely corresponds with that of the larger ones, so that a skeleton of the whole would exhibit little difference in its several parts. On the other side, a portion of another series of secondary leaflets is seen; but towards the extremity they merge again into a larger leaflet. Below these again, we have a complete pair of larger leaflets. If the whole of the leaf had been formed on this

FIG. 67.—LEAF OF GLEDITSIA, one of the Acacia tribe, showing curious varieties in the subdivisions of the leaflets.

last plan, it would have been simply *pinnate*. If on the plan of the lowest division, in which there is a complete series of secondary leaflets on each side, the leaf would have been *bi-pinnate*. And if the whole leaf had been constructed upon the plan of the minutely-subdivided portion of the second division, it would have been *tri-pinnate*.

239. These are some of the most interesting varieties in the form of leaves, depending upon the degree in which the parenchyma or cellular flesh is supplied, to fill up the interspaces between the veins. Of those which depend upon the various distribution of the veins themselves, it is not intended here to speak; since every plant furnishes materials for observation of these differences. In regard to the *size* of leaves, it may here be mentioned that, whilst in some species they are nearly microscopic, in others, especially of the Palm tribe, single leaves attain the length of from 30 to 40 feet.

240. There are some leaves possessed of the power of developing buds from their edges,—a fact which will hereafter (Chap. XII.) be shown to be important. One of these is the Bog-Orchis (*Malaxis paludosa*) of English marshes; in which these buds may be distinctly seen, though the whole plant is very small. A better example, however, is the *Bryophyllum calycinum*, which is a species inhabiting tropical climates, and known as the *air-plant* or *leaf-plant*, from the circumstance of a single leaf, without either stem or roots, being able to maintain its life, and even to grow and flower, whilst hung up in a damp and warm atmosphere, without the contact of soil to any part of it. The little buds,* which develope themselves at the edges of the leaves, may become perfect plants, before sepa-

FIG. 68.—LEAF OF BRYOPHYLLUM CALYCINUM, BEARING BUDS AT ITS EDGES.

rating themselves from the parent; but, when they have once formed their own leaves and root-fibres, they are but little connected with it, and may be detached without injury.

241. The usual form of leaves is often remarkably changed; and many of the varieties produced in different plants, seem to have for their object, to collect water from the atmosphere and convey it to the roots. The large expanded leaves of the *Arum* tribe, for example, have a deep channel down the midrib; and this is continued along the petiole, so that the water collected by the leaf is conveyed to the point of the stem from which it springs. In the common Teazel (*Dipsacus*) of our own fields, and the *Tillandsia*, or Wild Pine of South America, there are hollows capable of holding a considerable amount of water, at the point of union of the leaf-stalk with the stem.

242. But the most remarkable contrivances of this kind, are those known as *pitchers*. The plants furnished with these curious receptacles are termed Pitcher-plants; and several kinds of them are known. In the *Sarracenia*, which is a native of Canada, these pitchers may be distinctly seen to be formed, by the very deep channeling of leaves and leafless stalks, the edges of which fold towards and meet one another, so as to form a complete vase; the mouth being guarded by a sort of hood, formed by the top of the leaf. In the *Nepenthes*, or Chinese Pitcher-plant, the pitcher is of more complex and singular con-

FIG. 69.—DIFFERENT KINDS OF PITCHERS, *a*, pitcher of Sarracenia; *b*, pitcher of Nepenthes; *c*, pitcher of Cephalotus.

struction. The petiole, soon after it arises from the stem, spreads into a broad leafy expansion, which seems to perform the function of the true leaves; it then contracts, and forms a round tendril-like cord of several inches in length; and it then expands again, and is hollowed in its interior, so as to form a very capacious and elegant receptacle. The mouth of this is guarded by a separate little leafy cover, which is connected with it by a distinct joint; and this is regarded by botanists as the true leaf. In one more variety, the pitchers of the *Cephalotus utricularis*, or Monkey-cups of South America (so named, from its being reported that the monkeys quench their thirst with the fluid they contain,) the petiole seems to form the lid; and the pitcher itself is composed of the hollowed leaf, which hangs from it by a kind of hinge.

243. In regard to the functions of these curious organs, there is some difference of opinion. It seems probable that the pitcher of Sarracenia is a kind of fly-trap, which serves to catch insects, the decay of which may furnish materials for its growth. Its interior is beset with long bristly hairs, which point downwards; and at the bottom, there is poured forth from the plant, a honey-like secretion, which is very attractive to insects. They experience little difficulty in reaching it; but when they endeavour to return, they are checked by the downward projection of the hairs, and are caught like a rat in a trap. It has been observed that the plant does not thrive so well, in a place from which small insects are excluded; and there is good reason to believe, therefore, (especially since, as we shall presently see, a corresponding instance certainly exists, §. 246,) that they are in some way beneficial to its growth,—probably furnishing by their decomposition, when dead, a sort of manure which is useful to the plant.

244. In regard to the Nepenthes, no very positive statement can be given; and it is certain that, of the fluid which is found in the pitcher in the living plant, a part at least is poured into it from the plant itself; since it has been found to contain fluid, while quite immature, before the first opening of the lid. The interior is covered with downy hair; and it is probable that

this performs the same functions as in other cases, attracting moisture from the atmosphere by its numerous points. It has been observed, that the lid is closed in dry weather, as if to prevent loss of fluid by evaporation from the interior; but that, if the atmosphere be made very damp, and especially if the plants near it in the hot-house be watered, so as to cause a large quantity of watery vapour to surround it, the lid of the pitcher will open, and the quantity of water contained in it will soon show a considerable increase.

245. The most curious, perhaps, of all the Pitcher-plants at present known, is one which has hitherto only been observed in India, growing in its native forests; it is called the *Dischidia Rafflesiana*. It is a creeping plant, having a long twining stem, which is destitute of leaves until near its summit; and this may be a hundred or more feet from the roots, on which, therefore, it can scarcely depend for nourishment, by absorption of fluid from the ground. Its supplies of moisture from a tropical atmosphere would be very uncertain, if there were no provision for storing up what it occasionally collects; but with such a one it is furnished. The pitcher seems formed of a leaf, with its edges rolled towards each other and adherent; and the upper end or mouth, from which it is suspended, is quite open, and adapted to receive whatever moisture may descend from the air, whether in the form of rain or dew. It is accordingly always found to contain a considerable quantity of fluid, in which a number of small black ants are generally seen; these are probably attracted by it, and their decomposition may, as in the case of the Sarracenia, render it yet more nutritious to the plant. But the most curious part of the whole apparatus, is a tuft of absorbent fibres, resembling those of the roots; these are prolonged from the nearest part of the branch, or even from the stalk to which the pitcher is attached, and spread through the cavity. They may be regarded in the light of secondary roots, serving to introduce into the plant the fluid aliment collected in

FIG. 70. PITCHER OF DISCHIDIA; showing the tuft of root-like fibres prolonged into it from the adjoining twig.

these curious reservoirs, which may be compared to the stomachs of Animals.

246. One more curious modification of the leaf may be noticed;—that which forms the insect-catching trap of the *Dionæa muscipula*, a plant inhabiting the southern part of the United States, and commonly known as *Venus's Fly-trap.* In this plant, we find certain of the leaves fringed at their edges with a row of long spines, and endowed with the power of folding the two sides of the leaf towards each other, so as to enclose any thing between them which may have settled upon its surface. When thus folded, the spines cross each other in such a manner, as completely to prevent the escape of an insect, which may be thus captured. Upon each half of the blade of the leaf, there are three projecting thorns; and it is when either of these receives the slightest touch, that the two sides fold together, and form a complete trap; the walls of which seem to press more closely upon the captive, the more it struggles. Any unfortunate insect which alights upon the leaf, is thus speedily destroyed; and its decay appears to furnish the plant with nutriment beneficial to it. Plants of this kind, which have been kept in hot-houses in this country, from which insects were carefully excluded, have been observed to languish; but were restored by placing little bits of meat upon their traps,—the decay of these seeming to answer the same purpose. The petioles of the leaves which form these traps, are very much widened and flattened; forming leaf-like organs, which seem to perform the functions of true leaves.

FIG. 71.—DIONÆA MUSCIPULA.

247. Having now noticed the chief varieties of leaves as regards their external form, we shall proceed to consider their internal structure; and this exhibits a degree of complexity which would scarcely be anticipated. The internal structure of the leaf cannot be well examined, without a high magnifying power. It is necessary to cut the leaf across with a sharp knife, and then to pare off an excessively thin slice from the cut edge; so that when a section, exhibiting the thickness of the leaf, from one surface to the other, is placed under the Microscope, the light may be sent through it. A portion of such a section of the leaf of the Lily, which may be regarded as sufficiently characteristic of leaves in general, is shown in the accompanying figure.

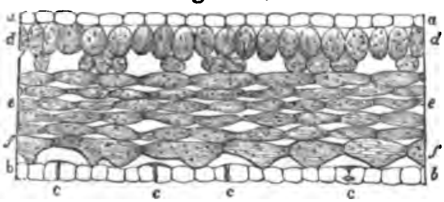

FIG. 72.—SECTION OF THE LEAF OF THE LILY; *a*, cells composing cuticle of upper surface; *b*, cells of cuticle of lower surface; *c*, *c*, stomata; *d*, upper closely-set layer of parenchyma; *e*, *f*, lower rows of cells more loosely arranged.

The colourless cells of the cuticle covering the upper surface of the leaf, are seen above; and those of the under cuticle, below. Between these, are seen a large number of shaded cells, which represent the coloured parenchyma or fleshy portion of the leaf. These are arranged with considerable regularity, and are packed very closely together beneath the upper surface; and there are scarcely any spaces between them in that part. Below, however, it is seen that the cells are of less regular form, and that they do not come into nearly such close contact, so that there are many spaces amongst them; which, communicating freely with each other, form what are termed the *intercellular* passages and spaces of the leaf.

248. The stomata are chiefly to be found in the lower surface; and they always open into the vacant spaces beneath the cuticle, and not against the cells in contact with it. It is the large proportion of these vacant spaces, which usually contain a considerable quantity of air, that occasions the colour of the under side of the leaf to be usually much lighter than that of the

upper. The cells of that part are themselves of a shade fully as deep; but a much smaller number of them lie against the transparent colourless cuticle. This may be easily seen, by cutting a thin slice from the under side of the leaf with a sharp knife, in such a manner as to detach a portion of the cuticle with the cells adherent to it; and on magnifying this it will be observed, how small a proportion of it is really rendered green, by the coloured tissue in contact with it. The large amount of air which these passages contain, is made evident, by putting a leaf in water under the receiver of an air-pump; and if the pressure be removed from above, by exhausting the air, a number of minute bubbles will be seen to issue from the pores of the leaf, forming a portion of the air previously contained in it.

249. Nearly all the leaves which assume the ordinary position, having one surface directed upwards and the other downwards, closely correspond with the one just adduced as an example in their general structure. There are, however, some curious exceptions. Not unfrequently we find the openings of many of the stomata extremely minute, or even entirely blocked up; especially in plants which inhabit hot and dry situations, and in which, therefore, less superfluous moisture has to be exhaled through them. It is in such that we find the cuticle formed of more than a simple row of cells. The *Oleander* is a very remarkable example of this structure. The upper cuticle consists of three rows of cells; and beneath this, we find two layers of green cells, packed with extreme regularity and closeness, so as not to leave any passages between them ; but between these and the lower cuticle, the texture of the parenchyma is very loose. The lower cuticle contains three, and sometimes four, layers of cells; and its exterior is covered with downy hairs. In its substance we find cavities, opening externally by a small orifice, and closely lined within by similar delicate hairs; and amongst these hairs, are situated extremely minute stomata. Now, as already mentioned, it seems that these hairs act as so many little rootlets; absorbing moisture with which they may be in contact, when the necessities of the plant require it; and nothing can more effectually aid them, than the little cavities

just mentioned, which are beautifully adapted to contain such minute quantities of water, as the atmosphere may deposit. Thus, the dryness of the soil and climate in which this species naturally exists, is compensated by the peculiar structure of its leaves; and it is, accordingly, one of the few plants that will flourish in a sitting-room, the air of which is too dry for the health of most others. Similar cavities have been observed in the Nepenthes and Dionæa.

250. There are many plants, however, whose leaves expose each side equally to the light; their surfaces being upright instead of horizontal. In these, both sides are usually formed alike, and their colours are the same. Upon examining their interior structure, it is found that both sides are equally furnished with intercellular passages; and that the number of stomata above these is nearly the same. This is the case, for example, in the common Iris. But there are some instances, in which the general plan of structure is completely reversed,—the stomata being restricted to the upper surface, and the upper part of the parenchyma being much looser in texture than the lower. This is the case, for example, with the Water-Lily, and other plants whose leaves float on the surface of the water. The thick spongy leaf of the Water-Lily contains a large amount of air-channels, which serve to give it buoyancy; but these are all immediately beneath the upper surface, and communicate with the external air through its numerous stomata; whilst in contact with the lower surface,—which, as it lies upon the water, is cut off from the actions that are usually performed by it,—are two rows of closely-packed cells, corresponding to those generally in contact with the upper surface. In all these instances, we observe such a beautiful adaptation of the structure of these wonderfully-organised beings, to the circumstances in which they are to live and grow, that the intelligent observer can scarcely feel a doubt of the Wisdom and Omnipotence of the Designing hand which contrived it.

CHAPTER VIII.

OF THE FUNCTIONS OF LEAVES.

251. It is in the Leaves, as already stated more than once, that those changes are effected, which convert the crude fluid absorbed by the roots (consisting as it does of little else than water, in which is dissolved a very minute proportion of the various matters existing in the surrounding soil,) into the *proper juice* or *nutritious sap*,—capable, not only of supplying to the different parts of the structure the materials necessary for the maintenance of their healthfulness, for the repair of injuries, and for the production of entirely new parts,—but also of furnishing the ingredients of those several products, which the various tribes of plants may be said almost to create from the elements around them, and which are so valuable to Man as articles of diet, as medicines, or as articles of use in his various manufactures. Many of these will have to be considered hereafter, under the head of *Secretions;* but it is interesting to observe here, that,—although almost every tribe of plants forms some substance peculiar to itself, some of which are of a highly poisonous character, whilst others are of the mildest and most wholesome nature,—they all originate in ascending sap, which is of a character nearly uniform in each tribe.

252. In this process of *Elaboration*, as this conversion has been termed, several distinct changes are involved. The first is the *concentration* of the fluid, by the loss of a considerable proportion of its water; so that the amount of solid matter, contained in any quantity of it, is much greater than before. This is effected by a process, which resembles the perspiration of Animals; a large quantity of watery vapour being given off,

under favourable circumstances, from the surface of the Leaves, as from the pores of the skin of a Man.

Exhalation.

253. If a glass vessel be placed with its mouth downwards, on the surface of a meadow or grass-plot, during a sunny afternoon in summer, it will speedily be rendered dim in the interior, by the watery vapour which will rise into it; and this will soon accumulate to such a degree, as to run down in drops. From an experiment of this kind, repeated by Bishop Watson during several successive days, on a meadow which had been cut during a very intense heat of the sun, and after several weeks had been passed without rain, it was calculated by him, that an acre of grass-land transpires in 24 hours not less than 6400 quarts of water. This is probably an exaggerated statement; as the Bishop does not seem to have been aware how completely transpiration is checked during the night; but it will serve to give an idea of the enormous amount of fluid, which must be thus disengaged. Any person walking in a meadow on which the sun is shining powerfully, especially in a hot day in summer, when the grass has not long previously been refreshed by rain, may observe a tremulous motion in distant objects, occasioned by the rising of the watery vapour; exactly resembling that which takes place along the sea-shore, when the sun shines strongly on the pebbles that have been left in a moistened state by the retreating tide.

254. It is necessary, however, to distinguish the *evaporation* which is the cause of the latter occurrence, from the peculiar function we are now considering; which, as we shall see, is influenced by circumstances that only act during the life of the Plant, in such a manner, as to prove it to be something of a different character, from that which we observe in dead substances. All moist bodies exposed to a tolerably warm and dry atmosphere have a tendency to become dry,—the fluid they contain, slowly passing off in the form of vapour. The rapidity with which this takes place, will depend upon the amount of heat to which they are exposed, and upon the degree of dryness

of the surrounding air. Every one knows that warmth is of great assistance, in drying moistened substances of any kind; and this results, from its promoting the conversion of the water into vapour. It may easily be observed, too, that a damp atmosphere retards the process; and the air sometimes has so large a quantity of vapour suspended in it, that it deposits it as a dew upon dry substances, instead of raising fresh moisture from damp ones.

255. Now the living fabrics of Plants are subject, like all other moist substances, to the loss of fluid by evaporation; and this would take place under the conditions just mentioned, from all the parts which have this character, were it not for the protection afforded by the cuticle. This membrane, as formerly stated, covers the whole surface of every plant, which is exposed to the air; and, from its peculiar nature, it is not liable to be thus influenced by heat or dryness of the atmosphere; so that it effectually protects, from the undue influence of these agents, the soft tissues beneath. The difference which results from the presence or absence of this cuticle, may be well seen, by comparing the long-continued freshness of the leaf of any Flowering-plant which is kept in the dark (so that its *exhalation*, or transpiration of fluid through the stomata, as presently to be explained, is prevented,) with the rapid shrivelling of the frond of a Sea-Weed, or of any Flowering-plant that naturally grows beneath the water, when equally exposed to the influence of a warm and dry atmosphere. And, as already noticed, the cuticle is almost invariably found to be the thickest and firmest, in plants which frequent very hot and dry situations.

256. Nevertheless the cuticle does not entirely check evaporation; but this takes place from the surface of a dead plant, or of any portion of one, as well as from one in the most active vegetation. The shrivelling of Apples long kept, and the loss of weight of Potatoes, are examples of this slow and gradual change. It may be stated, then, that Plants, like other moist soft substances, are liable to part with some portion of their fluid by evaporation, especially when exposed to a warm and dry atmosphere; but that the amount of this loss is far too small, to

account for the large quantity of vapour, which, as just stated, may be easily ascertained to pass off at certain times, from the surface of the living plant.

257. Now a few simple experiments will show, that there is a strong probability that this rapid transpiration takes place through the stomata. If a piece of glass be held near the *upper* surface of the leaf of a Vine, actively growing in a hot-house, little effect will be produced upon it; but if it be held near the *under* surface, the glass will soon be dimmed by the vapour; and in a short time longer, this will accumulate so as to form drops. As the upper surface of a vine-leaf is nearly destitute of stomata, whilst the lower is thickly covered with them, the disproportion in these effects is at once explained, if the transpiration really take place through these apertures. Similar experiments on other plants lead to the same general result. Where the stomata are equal in number on the two surfaces, both seem to transpire alike; and when neither possess stomata capable of action, the transpiration is scarcely to be observed. Again, if a plant, actively transpiring under the influence of sun-light, be carried into a dark room, its transpiration is immediately and almost entirely checked; and if its stomata be then examined, they will be found to have closed. Thus it appears almost unquestionable, that the rapid loss of fluid from the whole vegetable surface, but especially from the leaves, which constitutes a most important part of the economy of the living plant, is regulated by the number of stomata which each part contains, and by the degree in which light acts upon them (§. 94).

258. Still, this kind of transpiration (which, to distinguish it, may be termed *Exhalation*) is not altogether different in its character, from the common evaporation first described. It will be recollected, that the stomata open into large passages channelled out, as it were, in the fleshy substance of the leaf; and that the walls of these are everywhere composed of a very soft tissue, which is constantly kept moist by the crude sap conveyed so plentifully into the leaves. If, therefore, the atmosphere be admitted into these passages, a very large amount of evaporation must take place from their sides, which resemble, in the want of

any protection, the substance of plants habitually living under water; and this evaporation will be the more considerable, as the surface exposed in these passages is much greater than that of the leaf itself. The *exhalation* of fluid from the living plant, then, may be regarded in part as a kind of evaporation from its interior, and will be promoted by the warmth and dryness of the air around; but it is entirely controlled by the stomata, which, by admitting or excluding the air, permit or check it in accordance with the influence of light upon them. Still it cannot be regarded as entirely due to evaporation; as fluid is sometimes exhaled more rapidly than it can be removed by that process (§. 265); and we are probably to regard this secretion as really analogous to the cutaneous exhalation of Animals. (See ANIM. PHYSIOL., §. 371, 372.)

259. Thus, then, we see one important mode, in which *light* influences the growing Plant. No amount of heat can supply a deficiency of this agent; for, if it be excluded, *exhalation* is entirely prevented; and all the fluid that is transpired, has to pass off by the slow process of evaporation from the external surface only, which is not nearly sufficient for the required concentration of the sap. Moreover, when the exhalation is checked, absorption soon ceases; for the tissues become gorged with fluid, and are capable of containing no more. If a plant, accustomed to grow in open day, be kept for some time in the dark, it becomes unhealthy, and, as it were, dropsical; and will generally die, if not restored to its usual condition. This is not, however, the only process performed by the leaves, which is checked by the want of light; and therefore the unhealthiness which results cannot be imputed to it alone (§. 288).

260. We are now prepared to understand, then, the share which the leaves have, in promoting and maintaining the absorption of fluid by the roots. The exhalation which takes place in the leaves, has a corresponding effect with the combustion of oil at the top of the wick of a lamp,—occasioning a continual demand for fluid from below. If the flame be extinguished, the oil does not flow over the top of the wick, because the absorption of it ceases also; and so the action of the roots is

governed by that of the leaves, the former organs ceasing to absorb the fluid, when it is not drawn off by the latter. This connexion is not only shown by the experiment just mentioned, but by a still more remarkable one, which explains in great degree the cause of the ascent of the sap in the spring, after it has been nearly stationary during the winter. If a Vine be growing on the outside of a hot-house, and a single shoot be trained within, in the midst of winter, the warmth to which the latter is exposed, will cause its buds to swell and unfold themselves; whilst those on the outside are quite inactive. A demand for fluid will thus be occasioned along this particular branch; and this will be supplied by that existing in the vessels below. When these are emptied, they will be again supplied from the parts below them; and thus the motion will be propagated to that division of the roots, whose fibres are connected with those of the vegetating branch; these will absorb fluid for its support, whilst all the rest are completely at rest. In the spring of the year, when the cheerful rays of the sun call the whole of the buds into activity, the whole of the roots are similarly affected; and that the sap begins to move in the upper branches, before it commences ascending in the trunk, has been shown by experiment,—notches having been cut at intervals, by which the period of its flow could be ascertained in each part.

261. Various experiments have been made at different times, to ascertain the quantity of fluid thus exhaled by plants; and the results of many of them are very interesting. Those made by Dr. Woodward, 150 years ago, have been already noticed (§. 100), as indicating the large quantity of water absorbed. There is no great difficulty in ascertaining the amount upon a small scale; for if a plant be supplied with a known weight of water, and the weight it has gained during a certain time be deducted from this,—allowance being also made for the evaporation from the surface of the water, in which its roots are immersed, the quantity of which may be easily estimated,—the difference must be the proportion exhaled. This differs much in different plants, chiefly according to the rapidity of their growth.

262. It has been ascertained, that the young leaves and shoots of the Wild Cornel exhale twice their own weight of water daily. A common-sized Cabbage, in the twelve hours of daylight, was ascertained by Hales (one of the best experimenters upon this interesting subject), to exhale from 15 to 25 ounces daily, according to the light and warmth to which it was exposed. This quantity, in proportion to the amount of surface exposed by the leaves, is probably as great as most Plants furnish; and is more than is given off from the skin of Man in the same time. This has been reckoned to amount in twenty-four hours to about 25 ounces; which, as there is no great difference between day and night, would make 12½ ounces in twelve hours; admitting, therefore, that the surface of his body is about one-fourth less than that of the leaves of the Cabbage, and reckoning the perspiration of the latter at the mean, between the greatest and the least, it is still much greater than that of man.

263. The transpiration of a Sun-flower in full growth, during fifteen days and nights, was carefully observed by Hales. This plant was 3½ feet high, its weight 3 pounds, and the surface of its leaves was estimated at 5616 square inches,—or about 2½ times that of the human body. The average transpiration during the whole period, was found to be 20 ounces per day; but in one warm dry day, it was as much as 30 ounces. During a dry warm night, it lost 3 ounces—probably by simple evaporation; when the dew was sensible though small, it neither lost nor gained; and by heavy rain or dew, it gained 2 or 3 ounces. When this amount is compared with that perspired by Man, it may be shown that, if their *surfaces* were equal, the man would perspire 50, and the plant 15; but that, for equal *weights*, the plant exhales 17, while the man perspires 1. Experiments upon single leaves, when not too long separated from the plant so as to lose their vitality, yield fully as striking results. Thus a leaf of the Sun-flower, weighing 31½ grains, absorbed in four hours, by its petiole immersed in water, 25 grains of that fluid; the leaf had increased in weight only 4¹ grains; so that 20½ grains had disappeared by exhalation.—Thus a quantity equal in weight to the leaf itself, would have been exhaled in about six hours.

264. Experiments of this last kind may be very easily performed by any one who has command of a pair of scales adapted to weigh small substances; and it is well that the student should avail himself of such opportunities, for learning how to "put Nature to the question" in matters of this simple character, in order to cultivate habits of accuracy and caution, which are useful in every condition of life. Let him take several leaves of different plants,—such, for example, as the Vine, Oak, Elm, Beech, Lime, Apple, Pear,—weigh them separately, and estimate as nearly as he can the comparative surface presented by each. He should then place their footstalks in glasses or bottles of equal size, into which has been poured a certain weight of water, carefully ascertained to be the same in each; and he should place all these in similar circumstances for a certain time; having also a corresponding glass without a leaf, in order to estimate the amount of fluid lost from the surface of the water by evaporation. By ascertaining how much had been absorbed by each leaf, and the weight each had gained, he would thus be easily enabled to calculate the quantity it must have exhaled; and then, by comparing this with the extent of the surfaces of the different leaves, he would estimate the proportional rapidity of the process in the various species he had chosen,—care having been taken to select, in the first instance, trees in equal stages of growth, and leaves of a similar degree of freshness and development.

265. The watery vapour which is constantly, though insensibly, given off from the skin of Animals, is liable to accumulate in drops, and to form sensible perspiration, when from any cause it exceeds in quantity that which the air can carry away; either in consequence of an increased secretion or separation of it from the blood (as when a person exerts himself in warm weather), or from the atmosphere being already so loaded with dampness, that it cannot contain any additional moisture (ANIM. PHYSIOL., §§. 371, 372). In the same manner, some Plants exhale so rapidly at sunrise, when the heat of the air is not sufficient to enable it to carry off the disengaged moisture, that the fluid accumulates in drops at the points of the leaves, and has been

mistaken for dew. This, however, is not the case; since it has been observed on plants under shelter, as well as on those that are exposed; and it has been noticed also at other parts of the day. A similar accumulation of water in drops has been observed when plants have been electrified; by which process the amount of exhalation appears, for a time at least, to be considerably increased. It is perhaps in this manner, that an electric state of the atmosphere hastens the growth of some kinds of plants.

266. If plants are exposed to a light of too great intensity, especially if they possess many stomata, and are not well supplied with water, their tissue becomes dried up by the increased exhalation which then takes place, and which is not sufficiently counterbalanced by absorption, so that their vegetation is materially checked,—a fact of which we see abundant examples in dry sandy soils, and exposed situations. If, on the other hand, the leaves are shaded, and the roots freely supplied with moisture, the growth of the plant is active and luxuriant, but its tissue is soft, and altogether destitute of firmness. This, however, is partly due to the imperfect performance of another process shortly to be described as that of *digestion*. Plants of a very fleshy juicy character, termed *succulent*, in which there is usually a great deficiency, or even entire absence, of stomata, require a considerable amount of light to secure for them that regular discharge of moisture which they require; hence when Melons are grown in a frame, as many leaves as possible should be exposed to the influence of the sun's rays, and the accumulation of moisture within should be provided against. There are certain succulent plants, which, owing to their deficiency of stomata, may be preserved without moisture for many days or even weeks; and as their cuticle is so thick as to resist evaporation, it is often very difficult to kill and dry them for the purpose of placing them in collections. Of this kind are the *Sedums* or *Stone-crops*, of Britain, which have been known to push considerable shoots when placed under pressure; and many plants of tropical climates.

267. Besides these applications of theory to practice, there

are many others, which will readily arise from the knowledge of the character of this function, and of the causes on which it is dependent. Thus we learn from it, that the operation of transplanting should not be performed in the summer, when the exhalation is most active; since, the roots being always injured in greater or less degree, the process of absorption is imperfectly performed, and cannot supply the loss by exhalation; so that the plant is dried up. This evil may in some degree be guarded against, by watering the plant copiously; but it is much better to make the change either in early spring, or in the latter part of the autumn; when most plants are destitute of leaves, and therefore scarcely exhale at all; and when the function is performed with much inferior energy, in those which possess them.

268. Again, we see the reasonableness of the practice, which has been long known as a useful one, of keeping a nosegay, the freshness of which it is desired to preserve, in a dark room; since the check thus put to the exhalation which takes place, not only from the leaves, but also from the leafy surfaces of flowers, prevents the rapid withering which will otherwise occur. Even the light of lamps and candles is to a certain extent effectual, in maintaining this function; so that this is to be avoided, where, for any particular occasion, flowers which have been picked are to be preserved as nearly as possible in their previous blooming state. Such a plan, however, would prevent the expansion of any buds which the nosegay might include; since this (both in leaf-buds and flower-buds) depends upon the vigour with which the process is performed, and is hastened by light.

269. The water exhaled by plants is very nearly pure; so that what is furnished by different species, varies extremely little either in taste or odour. It has been remarked, however, that fluid thus obtained becomes foul sooner than ordinary water; and this is the case wherever organic matter, even in extremely minute proportion, is diffused through the fluid. The quantity of solid matter contained in 40 ounces of the liquid, exhaled from a Vine at the commencement of the summer, has been found to be only two grains; and no more than this was con-

tained in 105 ounces, from the same vine, at the conclusion of the summer. Even these minute quantities are sufficient to communicate a perceptible taint, when separated by their decay, into the gases of which they are composed, and of which the bulk is very much greater.

Absorption of Fluid by the Leaves.

270. Although the leaves of the higher plants are, without doubt, the special organs of exhalation, they also have the power, like the leafy surfaces of the lower tribes of plants, of supplying fluid nourishment, under peculiar circumstances, when the system requires it. It has been already shown, that it is only as we ascend the scale, that we begin to meet with distinct roots for the purpose of absorption;—the same general surface answering both purposes in the simplest tribes. And even where distinct root-fibres are developed, they are often closely connected with the leafy surface; these fibres being sent off from the under side of the leafy expansion of the Marchantia, and often from a similar part in the separate and delicate leaflets of Mosses.

271. It is not to be wondered at, then, that the leaves of higher plants should be capable of supplying, in some degree, the functions of the roots; when these are absent or imperfect, or are unable, from the nature of the soil which surrounds them, to obtain a sufficient supply of fluid nourishment. Not unfrequently the roots, where they exist, serve merely to fix the plant, finding their way into the crevices of the hard dry soil, or of the barren rock, on which it grows; and then it must be altogether dependent upon the moisture it imbibes through the general surface. In such cases the function of exhalation is but feebly performed; and all the processes of growth are proportionably slow. Plants of this description flourish best near the sea-shore, where there is always a certain amount of moisture in the atmosphere: and especially, too, in tropical regions, where the constant high temperature increases the evaporation from the surface of the water, and at the same time enables the atmosphere to dissolve a greater quantity of watery vapour. It is wonderful to see the precipitous faces of rocks apparently the most barren,

studded here and there with plants of the *Cactus* and *Orchis* tribes; the former exciting attention by the brilliancy of their blossoms, and the latter by the strange shapes they often present. In many of the Cacti growing in such situations, the stems contain a considerable amount of fluid; which, though insipid, is wholesome, and is freely used as a cooling drink in fevers, by the natives of the countries in which these plants abound.

272. Many of the *Orchis* tribe (as well as other plants) grow entirely in the air; spreading themselves over the surface of trees, from which their roots hang freely down like fringes. Such attain their greatest luxuriance, in the forests of the tropical parts of South America; and here a constantly moist state of the atmosphere is maintained, by the exhalation of the trees, upon which they cluster. When grown in hot-houses in this country,

FIG. 73.—AERIDES ARACHNOIDES.

they require that the atmosphere should be rendered artificially moist, as well as warm; and that their roots should be enabled to spread themselves freely through the air, and should not be

confined within pots. The luxuriance which such plants often exhibit, sufficiently proves, that the atmosphere contains all the materials, which are necessary for the growth even of the highest plants; and that, if the structure is adapted to imbibe them from it, no other kind of supply is necessary.

273. A fact familiar to every one, who has bestowed common notice on the processes of vegetation, equally proves that the leaves, as well as the roots, are capable of absorption. When plants are faded by the intense action of light and heat, and have suffered from deficiency of water, they are observed to revive rapidly, when their surfaces are moistened, even if no fluid have been supplied to the roots. More precise experiments lead to the same result. It has been found that leaves placed with one of their surfaces upon water, would remain fresh for several months; the absorption through it counterbalancing the transpiration through the other. From a considerable number of experiments on different kinds (though this, again, is a subject which any one may investigate with great ease, and with the certainty of arriving at new and interesting results with a very little trouble), it seems to be ascertained, that the leaves of trees and shrubs retain their verdure longest, when the lower side is placed in contact with water; whilst the leaves of herbaceous plants absorb most readily by their upper surface, or in an equal degree by both. Thus, leaves of the White Mulberry, placed with their upper side in water, faded on the fifth day; whilst those which absorbed by the lower surface, remained fresh nearly six months. This effect, however, was no doubt due in part, to the greater degree of obstruction to the loss of fluid by transpiration, in the second case than in the first; the stomata being principally situated on the lower surface. But in experiments on other plants, in which they are similarly disposed, the contrary result has been observed. Thus, leaves of the Nettle, whose inferior surface only was kept moist, faded at the end of three weeks; whilst others whose upper surface was in contact with water, lived for two months. Lastly, the leaves of the Sunflower, Kidney-bean, Cabbage, and of many other plants, were observed to remain fresh for the same

length of time, by whichever surface they received their supply of fluid.

274. This arrangement is admirably adapted, for obtaining the greatest supply of the moisture, contained in the lowest layer of the atmosphere; for when, by the cooling of the earth's surface, which takes place on a clear night, this moisture falls in the form of dew, it will manifestly be received on the upper sides of the leaves of plants, which are but little raised above the ground; whilst, on the other hand, the leaves of more elevated trees would not benefit by this deposition, being situated above its influence; and these would receive and imbibe the vapour, as it afterwards rises from the surface of the moistened earth. We thus learn that, if it be desired to revive drooping or sickly plants or trees by the application of moisture, the mode in which it should be distributed over them will depend upon their size; if they be herbaceous plants, they should be watered from above; and if they be tall shrubs or trees, the water should be thrown up by a syringe from below.

275. The absorbing power of leaves has been shown by other satisfactory experiments. Some plants of *Mercurialis* (Mercury) were placed in water, some of them being immersed by their roots, and the others touching it by a part of their leaves alone, a small shoot of each being kept out, for the purpose of comparison with the rest. After five or six weeks, the shoots of the plants which were nourished by the leaves, differed little in vigour from those which had been supplied by the roots. Experiments upon single leaves, which have already partially faded, are still more striking. Some leaves of *Potamogeton natans* (Pond-weed), after being wiped dry, were weighed; and after remaining out of the water for two hours, they were found to have lost from 3½ to 5½ grains each. They were then put in water; and after the lapse of two hours more, were again wiped dry and weighed. It was then found, that they had severally gained from 3 to 5 grains each; and this increase (which was also evident from the restoration of their natural freshness and plumpness) could only have taken place by absorption through the cuticle, as the cut ends of their footstalks were defended by soft cement.

276. Other experiments show the remarkable influence of dew, in supplying nourishment to plants. Two similar leaves of the *Plantago lanceolata* (Ribwort Plantain), equally faded, and each weighing 8 grains, were compared; one having its footstalk immersed in water, and the other being exposed to dew. On the following morning, the first had gained but one grain, whilst the second (after the adherent moisture was wiped off) was found to have gained a grain and a half. A similar experiment was then tried upon two leaves of *Verbascum* (Mullein), each of which weighed 13 grains in the first instance. The one whose footstalk was immersed in water gained 2¼ grains; whilst the other gained 4 grains. Many other experiments of a similar kind might be related; but these are sufficient to show, that leaves whose tissue has been deprived of fluid, have the power of replacing it by absorption from water placed in contact with them, or from a moist atmosphere. This power is probably exercised, however, in the majority of plants, only when their roots cannot from any cause obtain for them an adequate supply; and at other times the leaves are organs of exhalation only.

277. The influence of dew and of a moist atmosphere in maintaining vegetation, is often very remarkable in tropical islands, where no rain falls for months together, and where the soil is so parched by the burning sun, as scarcely to yield a particle of fluid to the plants growing upon it. The proximity of the sea occasions the atmosphere of these islands to contain a large quantity of vapour, which, when the temperature of the soil falls at night, is deposited as an abundant dew; and, in consequence, they exhibit a luxuriant vegetation, under circumstances which would cause an inland country to appear completely parched. In the year 1840, the preservation of the young corn during the hot and dry month of April, in many parts of England, was owing to the heavy dews. In consequence of the wetness of the preceding autumn and winter, very little grain had been put into the ground before February; and, as there was little rain from that time, the surface of the ground was not sufficiently moist, to cause the rapid germination and growth of the young plants. Towards the middle of April the sun began

to shine with great power; and as no rain fell, it was much feared that the young plants, not having length enough of root to penetrate deep into the soil, would be starved for want of nourishment. This was supplied to them, however, in two ways —partly by the dews, which, in consequence of the clearness of the nights, were heavy; and partly by the action of the powerful sun upon the deeper part of the soil, which had been drenched (as it were) with moisture by the rain of the preceding autumn, so that when it became heated, it sent up a large quantity of vapour, which was probably absorbed both by roots and leaves.

278. This absorption of fluid by the leaves, appears to take place chiefly through the membrane of the cuticle; but more particularly by the downy hairs, which seem to act as so many root-fibres. They are chiefly developed, as already stated (§. 96), upon plants which grow in situations in which they are much exposed to light, and to a dry atmosphere; whilst the same species in damp shady situations will not be furnished with any. It has been noticed that they lift up their points, and separate from one another, at the approach of the evening dew, which collects in minute drops around them; and that they fall down again, and form a layer of minute cavities on the cuticle, as soon as the heat of the sun begins to be perceived. On comparing the increase in weight when exposed to dew, in plants thickly furnished with hairs, and possessing few or no stomata, with that manifested by plants having a smooth surface and many stomata, it is seen that the former is much the greatest; and that it also surpasses, in about the same proportion, the weight gained by immersing the footstalk in water. Thus two heads of *Marrubium vulgare* (Common Horehound), the original weight of which was 15 grains each, were placed, one with its stalk in the water, and the other in a place exposed to dew, for a night; the first was found to have gained 2 grains, and the second 5 grains. Both were exposed to dew during the next night; and on the following morning they each weighed 23 grains, having both gained 8 grains, of which the first had acquired 6 in that night. A withered stem of *Cerastium Alpinum* (Alpine Chickweed) weighing 5 grains, gained 6 grains by exposure to dew for two nights.

On Respiration.

279. The concentration of the crude sap by the loss of its superfluous fluid, and the occasional absorption of what may be necessary to supply the amount insufficiently afforded by the roots, are by no means the only functions of the leaves; nor can they be regarded as the most important. These organs supply also the means of getting rid of a certain superfluous product, to retain which within the system (at least in the form in which it is set free) would be injurious and even destructive; and they serve the equally important purpose of introducing, from the air, the element which chiefly gives firmness and solidity to the vegetable tissue.

280. It is well known that, when an animal is confined in a limited quantity of air, it soon vitiates it, or renders it unwholesome; so that free ventilation, by which the foul air is replaced by that which is fresh, is one of the most important means of the preservation of health. Now this change in the air is effected by the removal of its oxygen, which is the element that chiefly supports the life of all beings; and by the substitution of carbonic acid gas set free from the lungs of the animal. Thus the blood is purified by the removal of a noxious ingredient; and is rendered more capable of maintaining the life of the system, by receiving one of the opposite character; and this change is manifested in its aspect, as well as in its properties,—the dark purple blood of the veins being converted, by exposure to the action of the air in the lungs, into the bright scarlet fluid of the arteries. (See Anim. Physiol. Chap. vi.)

281. If the carbonic acid, which the blood takes up in its passage through the vessels of the body, be not set free in this manner, in consequence of any obstruction to the admission of air into the lungs, or other similar cause, the animal dies. The throwing-off this superfluous ingredient is, indeed, one of the most constant of all the processes of the animal economy; and there is good reason that it should be so, since it is set at liberty by the continual decay, to which all parts of the living body are more or less subject (the softer ones, however, much more rapidly

than the hard ones), and which is only prevented from becoming manifest, by the mode in which the decomposed particles are thus separated and carried out of the system, their places being supplied by others newly deposited from the nutritious fluid.

282. Now this process of Respiration is as constant and universal in the Vegetable Kingdom as it is in the Animal; and it is only because a change, apparently of a contrary nature, sometimes obscures its effects, that it is not generally recognised. In fact, a healthy *plant* placed in a limited quantity of air, and exposed to the usual amount of daylight, will (so long, at least, as it remains healthy) add to its purity; and will even restore the freshness of that, which has been vitiated by an animal. But it is not the less true, that there is a *constant* extrication of carbonic acid; for this may be very easily proved to take place, even while carbon is being absorbed. If, for instance, a few small healthy plants be placed under a glass vessel, from which all carbonic acid has been previously removed, and allowed to remain there even in sunlight for a few hours, they will be found to have set free a small portion of carbonic acid; this may be detected, by shaking the air contained in the vessel with some lime-water, which it will render turbid. When the same experiment is tried in the shade, or by night, the quantity of carbonic acid found in the air is considerably greater.

283. There are two periods during the life of a Plant, when this liberation of carbonic acid gas goes on with great energy. One is in the *Germination* of the seed; and here we can distinctly trace the object which is gained, by the abstraction of the oxygen from the surrounding air, and by the conversion of it into this gas so opposite in its properties. In the seed, when approaching maturity, a considerable quantity of starchy matter is laid up for the nourishment of the embryo; and this may remain unaltered for a long series of years, if the seed be not placed in those conditions which excite it to grow. But if it be exposed to warmth, moisture, and air (or any mixture of gases containing oxygen), it will *sprout* or germinate. In this process the starch, which (while it remains such) is unfit for the nourishment of the embryo that is being developed, is converted into

sugar, which forms an appropriate food for it. Had Sugar been deposited in the first instance, it would have probably undergone fermentation, and would have thus lost its utility, before the time came for its office to be performed; but the deposition of *Starch*, which can remain unchanged for almost any length of time, and which can at any time be converted into sugar, secures these objects in the most effectual manner. Starch differs but little from sugar in chemical composition, except in containing one additional proportion of carbon. When germination commences, oxygen is absorbed by the seed, in the substance of which it combines with the carbon that is to be set free from it; and a large quantity of carbonic acid is then given forth again to the air, whilst, in the same proportion, the starch is converted into sugar.

284. It is in this manner, that the nearly tasteless barley is changed into sweet malt; and the change in the air around, exhibits to us the function of respiration in its least complex form. Darkness favours it; since, as will presently be shown, a change of contrary character is favoured by light. It is an interesting fact that, after many trials, germination has been found to take place most readily in an atmosphere consisting of 1 part Oxygen, and 3 parts Nitrogen; which is nearly the proportion of these ingredients, in the air we breathe. If the quantity of oxygen is much increased, the seed loses its carbon too rapidly, and the young plant is feeble; and if the proportion is too small, carbon is not lost in sufficient amount, and the young plant is scarcely capable of being roused into life.

285. The changes which take place in Flowering, are very similar to those occurring in germination. At the bottom of the flower is usually a fleshy expanded body, into which its different parts are inserted; this is called the *disk* or *receptacle*. Here, too, there seems to be a sort of reservoir of starchy matter, for the nourishment of the newly-produced germs; which is converted, as in the other case, into sugar. A part of this is probably absorbed into the interior; but the superfluous portion flows off in the form of honey. During the conversion of the starch into sugar, a large quantity of carbonic acid is substituted for the

oxygen, which is absorbed; and this appears to be principally effected by the interior organs of the flower. It has been found that an Arum-flower, whilst in bud, consumed in twenty-four hours 5 or 6 times its bulk of oxygen; during the expansion of the flower 30 times; and during its withering, 5 times. When the outer leafy parts of the flower were removed, it was found that the oxygen consumed by the interior organs was much greater in proportion. In one instance, the stamens and pistil of an Arum consumed in twenty-four hours 132 times their bulk of oxygen. It has also been observed that double flowers, in which these internal organs are replaced by leafy parts, vitiate the air much less than the single flowers, in which the former are perfect.

Fixation of Carbon.

286. The process of Respiration, then, in Plants as in Animals, appears essential to the life and health of the system; and, though more energetic at some periods than at others, it is constantly performed. If a plant be surrounded by an atmosphere already vitiated, and be secluded from the influence of light, its respiration will be (like that of an animal in similar circumstances) so much impeded, that its speedy death will follow. But a very different result occurs, if it be exposed to strong or even moderate daylight. The carbonic acid of the air will be decomposed by the *green* parts of the surface of the plant; and the solid carbon will be *fixed* within its tissues, while the oxygen will be set free, so as to restore the purity of the air. It is in the performance of this function, that the leaves, from the extent of the green surface they present, are peculiarly energetic; for in that of respiration, they only share with all the rest of the softer portions of the exterior; and in fact the dark surfaces seem to have more to do in it than the light.

287. Now this *Fixation* of carbon, as it is termed, which antagonises so remarkably the effects of the process of respiration, may be regarded as in some degree analogous to the function of *digestion* in animals. In the solid food of all animals, whether it be of an animal or vegetable character, carbon is one of the

principal ingredients; and vegetables also require this, for the formation of their solid tissues. The proportion which they take in by the roots is but small; and what they require in addition, is obtained in this manner from the atmosphere; as they possess no stomachs, by which it may be introduced in a solid form into the system. It is, then, chiefly of the water absorbed by the roots, and the carbon thus taken in by the leaves, that the elaborated sap or nutritious juice of the plant consists; and the constant liberation of carbonic acid from the general surface, in which the process of respiration consists, appears more necessary to preserve the healthfulness of the general system (by carrying off what is in a state of commencing decay), than to change the character of this juice.

288. The proportion of carbonic acid, in which a healthy plant will thrive, under the influence of strong sun-light, is not less than 7 or 8 per cent.: but a much smaller proportion than this would soon be fatal to it, if grown in the shade. It is to a peculiar compound formed in the cells of the green surfaces, of which the carbon introduced from the air is an essential ingredient, that the colour is due; and as this fixation can only take place under the influence of sun-light (artificial light, even the most powerful, having no influence on it), plants which grow in dark situations are either in part or entirely destitute of colour. They are then said to be *etiolated* or blanched; and the effect is purposely produced in many instances. If the absorption of carbon from the atmosphere is checked, the fluids have a much more watery character, and do not contain their peculiar principles in nearly so much abundance. Hence many plants, which are rank to the taste and stringy in consistence, when growing in their natural conditions, may be rendered much more palatable by being blanched,—neither the peculiar secretions to which the rankness is due, nor the woody fibres which occasion its toughness, being then formed in the same degree. For this reason it is that Celery, Sea-kale, and many other vegetables are blanched,—earth being heaped over their young shoots, so as to keep them from the light. As exhalation will also be checked by the same process, the tissue becomes distended with

fluid, and acquires that succulence or juiciness, which is so much valued in such vegetables.

289. But though the *bulk* of plants which are undergoing this treatment, may considerably increase, yet the *weight* of their *solid* contents diminishes; for during the whole period, respiration is going on; and, as there is thus a constant loss of carbon, whilst little or none is introduced, it follows that, if the tissues were dried by heat, they would shrink to less than their former amount. This is found to be the case; and it is also true of a seed in the process of sprouting or germinating, which constantly diminishes in the weight of its *solid* contents, up to the time when some of the new-formed leafy surfaces become green, and begin to absorb carbon from the atmosphere.

290. At this period of the growth of the young plant, it may be regarded as having a curious analogy with the tribe of Fungi. Both are supplied with nutriment already organised; for whilst the one has it previously stored up by its parent, the other receives it from the decomposing matter, upon which alone it can grow. Both are developed most rapidly and luxuriantly in the absence of light, if well supplied at the same time with warmth and moisture. And the Fungi, like the germinating seed, give out a large quantity of carbonic acid to the atmosphere, without receiving any carbon from it; since the peculiar character of the aliment they imbibe by their roots, renders any additional supply of this ingredient unnecessary. In the Fungi, therefore, we have the process of respiration as distinct and easily understood, as in Animals,—both classes of being subsisting upon food already organised, in which there is a large proportion of carbon.

291. The process of *digestion* is confined, as before stated, to the leaves, and to those green surfaces of plants, which correspond with them in function; but that of *respiration*, although performed by the leaves more energetically than by any other part (at least during the ordinary process of growth), is not restricted to them, but is partially effected by the other surfaces, and even by the roots. The knowledge of this fact is important; since, through ignorance of it, much valuable timber has been

destroyed. Several years ago, during alterations in Hyde Park, a considerable depth of soil was added to a part of it, in which grew some fine elm-trees; the trunks of these were protected from pressure by circular walls, but at a little distance from them; nevertheless, the trees languished and died. Now the reason of this was simply, that the roots being covered with too great a depth of earth, could not exercise their usual function of respiration; to perform which, they seem generally to direct their course as near the surface of the ground, as is consistent with the support they have to afford to the plant.

Influence of Vegetation on the Atmosphere.

292. Much discussion has taken place upon the question, whether or not vegetation is upon the whole serviceable in purifying the air;—that is, whether plants do altogether give out most carbonic acid, or most oxygen, to the atmosphere. By Priestley it was maintained, that the latter was the *only* effect of vegetation; and that Plants and Animals are thus constantly effecting changes in the atmosphere, which counterbalance one another. Subsequent experiments seemed to show, however, that the carbonic acid given out during the night, might equal or even exceed in amount the oxygen given out by day; but this was probably due to the employment of plants, which had become unhealthy by being kept in a limited quantity of air, and which had not been exposed to a fair degree of light. For it has been recently shown by Dr. Daubeny of Oxford, that in fine weather, a plant consisting chiefly of leaves and stems, if confined in a capacious vessel, and duly supplied with carbonic acid during sunshine, as fast as it removes it, will go on adding to the proportion of oxygen present, so long as it continues healthy;—the slight diminution of oxygen and increase of carbonic acid, which take place during the night, bearing no considerable proportion to the degree, in which the contrary effect occurs by day.

293. Thus we see that "the two great organised kingdoms of nature are made to co-operate in the execution of the same design; each ministering to the other, and preserving that due balance in the constitution of the atmosphere, which adapts it

to the welfare and activity of every order of beings, and which would soon be destroyed, were the operations of any one of them to be suspended. It is impossible to contemplate so special an adjustment of opposite effects, without admiring this beautiful dispensation of Providence: extending over so vast a scale of being, and demonstrating the unity of plan upon which the whole system of organised creation has been devised."

294. And yet Man, in his ignorance, and his thirst for worldly gain, has done his utmost to destroy this beautiful and harmonious plan. It was evidently the intention of the Creator, that Animal and Vegetable life should everywhere exist together; so that the baneful influence which the former is constantly exercising upon the air, whose purity is so essential to its maintenance, should be counteracted by the latter. Nothing is more prejudicial, therefore, to the health of a large population, than the close packing which too many of our cities exhibit; hundreds of thousands of men, with manufactories of all kinds, the smoke and vapours of which are still more injurious than the foul air produced by their own respiration, being crowded together in the smallest possible compass, with scarcely the intervention of an open space on which the light and air of heaven may freely play, and without any opportunity for the growth of any kind of vegetation, sufficiently luxuriant to give pleasure to the eye, or sufficiently energetic to answer its natural purpose. For the close confined air of towns is almost as injurious to plants as to animals; the smoke which is continually hovering above them, prevents their enjoyment of the clear bright sunshine which they require for their health; and the fine dust, that is so constantly floating in the atmosphere, covers over their surfaces, and clogs up their pores.

295. Hence the low stunted dingy vegetation, which the squares and open spaces of some of our large towns exhibit, is of little service; but extensive areas fit for the growth of lofty trees, are so beneficial in such situations, that they have been called *the lungs* of large cities,—so important is the purification of the air which they effect. It is true that they may occasion some degree of dampness in the immediate neighbourhood; but

this evil is much more than counterbalanced by the good they effect; so that the cutting down of a tree in the midst of a large town, without some very strong reason, should be regarded as an offence not easily to be atoned for. It is much to be wished, that the law of the land required such an open space to be set apart, whenever the population of an extending town or district increases beyond a certain amount.

296. There is good reason to believe, that Confervæ and other aquatic plants exercise a similarly important influence, in keeping the water they inhabit in a state fit for the support of animal life; since it appears probable, that they absorb the products of the decomposition of that foul matter, by which all ponds and streams are constantly being polluted; and that at the same time they yield a supply of oxygen to the water. It is a fact well known, that Fishes are never so healthy in reservoirs destitute of aquatic plants, as in those in which they abound. The lower Cryptogamia appear to flourish better than higher plants would do, when supplied with a large quantity of carbonic acid, whilst the amount of light they receive is but moderate. In the lake Solfatara in Italy, are several floating islands, consisting chiefly of Confervæ and other cellular plants; which are copiously supplied with nutriment by the carbonic acid, that is constantly escaping from the bottom of the lake, with a violence which makes the water appear as if boiling.

297. Under favourable circumstances, too, the highest plants are able to continue appropriating a larger proportion of carbon than that commonly existing in the air. The vegetation around the springs in the valley of Gottingen, which abound in carbonic acid, is very rich and luxuriant; appearing several weeks earlier in spring, and continuing much later in autumn, than at other spots of the same district. But it is probable that, taking the average of the whole globe and of all seasons, the quantity of carbonic acid commonly existing in the air, is that which is most adapted to maintain the life of the race of Plants at present inhabiting its surface, as well as to interfere as little as possible with the well-being of the Animal creation.

298. It is not improbable, however, that, in former epochs

of the earth's history, a much larger amount of carbonic acid existed in the atmosphere. At the time of the existence of those vast pine-forests, which, in their decomposed state, supply us with such an enormous amount of that most valuable article of England's wealth—*coal*—an article more really valuable to her than the mines of Peru,—scarcely any land animals seem to have existed; and these were of kinds, which are now found to be capable of breathing a comparatively impure air. The great luxuriance of these forests, as indicated by the vast amount of their remains, and by more perfect specimens which have been preserved to us, has led to the opinion that, at the period of their growth, more carbonic acid existed in the atmosphere than at present; and that, in fact, it has from that time been gradually undergoing purification, by the processes of vegetable growth: and has at last become fit for the residence of the higher animals.

Return of the Elaborated Sap.

299. The crude sap is brought into the leaves, by the vessels which are connected with the woody portion of the stem; and these branch out and subdivide in the veins, so as speedily to distribute the fluid over the whole surface. After undergoing the various changes now described, it is collected again by a system of vessels, which lie nearer the lower surface, and which communicate with the bark. These are principally of the kind formerly described as *vessels of the latex;* and through these the descending sap, now completely changed in its properties, is returned to the stem. This fluid contains the materials of all the products of the vegetable system;—the elements of the organised tissues, the secretions which give solidity and toughness to the wood, those which occasion the delicious odours that so abound among plants, and those which supply so many useful and important products, with which the comfort and luxury of Man are largely connected. All these are entirely dependent on the action of the leaves; and the action of the leaves is dependent upon the supply of that amount of light and heat, but especially the former, which each species of plant requires.

300. It not unfrequently happens that a plant will *grow* under a considerable change of circumstances; but will not form its peculiar products in anything like the same perfection, as in its natural condition. Thus, Tobacco may be raised in this country, but it is far inferior to that of warmer and more sunny climes; as is also the scent of the Rose, which does not here furnish enough of the very fragrant oil termed Otto of Roses, to make it worth while to cultivate the plant for this purpose, although the oil is imported from the East at an enormous price. On the other hand, the common Lavender is more fragrant in this country, than in the South of Europe. In general, plants grown in warmer climates, where the sky is less clouded, form secretions more active in every respect than those of temperate regions;—substances, for example, which are more powerful as medicines, or which have stronger and brighter colours, such as make them useful as dyes.

Development and Death of Leaves.

301. When leaves are first produced, they are small, very delicate in texture, pale in colour, and packed very closely together, forming what is called a leaf-bud. Some of the outer ones are of firmer texture and darker colour, and fold over each other like the tiles on the roof of a house, so as to protect the soft and delicate organs within. These are commonly termed *scales*, being often very different from the true leaves in aspect; but there is no real distinction between them; for, on opening the bud, it is easily seen, that their inner layers gradually approach the true leaves, in appearance as well as in structure, and at last pass almost imperceptibly into them. The young leaves are most beautifully folded together, in such a manner as to occupy the least possible space; and the peculiar mode

FIG. 74. — LEAF-BUDS ABOUT TO UNFOLD; *a*, *a*, marks of the attachment of leaves, just above which buds are always developed.

in which this is done, varies in different tribes of plants. Any one may examine it, with the certainty of finding what will greatly interest him, by cutting across the leaf-buds with a sharp knife, when they are swelling, but before they have begun to expand. The outer scales are sometimes covered with a thick down, which may serve as a protection to them against the cold; and sometimes they are coated over with a gluey substance, as in the horse-chesnut,—which seems a very efficient guard.

302. The young leaves, in most leaf-buds, may be easily observed to be arranged around a common centre or axis. When the bud lengthens, the insertions of the leaves, which were at first close together, are separated by the lengthening of the branch which bears them; and they then generally assume something of a spiral or rather a *corkscrew-like* arrangement round it, which is often very apparent. In fact this may be regarded as the regular mode in which leaves are arranged upon any part of the stem or branches of a tree. Starting from any one leaf, we shall generally find the next leaf not exactly above or below that one, but a little to one side of the perpendicular; the next a little to one side of that;—and so on, until we come directly over the one from which we set off. We shall have thus made a spiral round the stem; and the number of leaves we meet with in its course, varies in different species of plants. Sometimes it amounts to twenty or more. Sometimes we only find two; in this case each leaf is nearly on the opposite side of the stem from the other, but higher up or lower down. Leaves are said in all these cases to be *alternate*. The point of the stem from which a leaf originates, is called a *node;* and the space between two nodes is called an *internode*.

303. Now although it may be considered as the *regular* kind of growth, for a branch to lengthen equally throughout, yet we not unfrequently meet with varieties in the arrangement of leaves, occasioned by the cessation of growth at particular points. Thus, if the internode between any two alternate leaves is not developed, the leaves will be *opposite* to each other. Again, where each spiral turn contains several leaves, if all the inter-

nodes between the highest and lowest be undeveloped, these leaves will arise from the same point of the branch, still growing, however, in their proper directions; so that a complete circle of leaves, resembling that of the leafy parts of a regular flower, will be produced; this is called a *whorl* or *verticil*. In some instances, however, it would perhaps be more proper to consider these as leaflets,—parts of one leaf; or as so many leaves upon one node of the stem. Of such, an example is seen in Fig. 75. There are some plants which exhibit the true spiral arrangement, as their regular mode of growth; others in which we constantly find the leaves opposite; and in some they are always verticillate.

FIG. 75.

304. But there are many species, which present differences in the arrangement of the various parts in the same individual, according to the circumstances under which each part has been developed; and it is by such examples that we are able to discern the connection between the several modes of growth. Thus, in the *Rhododendron*, we find the leaves sometimes opposite, sometimes alternate. In the *Honeysuckle*, the leaves are naturally opposite; but the pairs are broken up, and the leaves carried to a distance from one another, by anything which causes an increased development of the stem; just as when any leaf-bud (which has the young leaves arranged in a series of whorls, one above or within another) is elongated into a branch. On the other hand, in the *Strawberry*, the leaves which are usually alternate, become opposite or whorled at intervals. It is to be remarked that, when leaves are opposite, the several pairs are not in a line with one another above and below; but each is at right angles to the next; so that, if the internode between two pairs were undeveloped, a whorl of four leaves would be produced. Again, when one whorl is developed near another, their leaves do not issue from corresponding points in the stem, but are arranged in such a manner that the leaves of one arise from what seem to be the *intervals* of those of the other, so that the whorls are *alternate* to each other. The knowledge of this fact

will be seen to be important, when the structure of the flower is described; as it will then be shown, that its several parts are arranged upon the same principle with leaves.*

305. It is by the development of leaf-buds into branches bearing leaves, and capable of producing flowers and fruit, that the tree or plant is increased in size. The leaf-bud has also the power of developing roots, if removed from the parent, and may thus form a completely independent structure. It is by separating the buds, and by placing these in circumstances favourable to their growth, that any particular variety of plant may be propagated more certainly than by seeds. Even whilst still remaining attached to each other, the leaf-buds not unfrequently become really independent of each other and of the parent; those, for instance, which are formed at the end of the runner or creeping stem of the Strawberry, send down roots into the soil, and thus absorb their nourishment directly from it. As every bud is capable of maintaining an independent existence, it may be regarded as in some degree a distinct individual; and thus a tree would not be one being, but a collection of many. This is in part true; still it must be remembered that, while all remaining upon one stem, the buds are almost entirely dependent upon it for nourishment, and are all liable to be influenced in the same manner, by any circumstances whi h affect it.

306. Still it is quite possible for some buds to live while others die. Thus if arsenic be introduced into any portion of the sapwood, it will give such a poisonous character to the fluid, that all the buds and branches in the line above it will be killed, the others remaining unaffected. It has even occurred, that a single bud at the summit of a stem has preserved its life, whilst the vitality of all the others, and of the stem, has been in some manner destroyed; and that from this bud have been sent down bundles of root-fibres, between the bark and wood of the dead stem, which, when they have reached the ground, afforded abundant supplies of nutriment to the expanding bud; and this has subsequently grown into a perfect tree, enclosing the original dead stem within its trunk. The original root-fibres are, in such a case, surrounded in the ensuing year by another layer

more resembling wood, and this in the next season by another; so that this portion of the structure, like the aerial roots of the Pandanus, may be regarded in the light either of stem or roots,—an idea which may, perhaps, be applied to the woody stem in general.

307. Leaf-buds are always formed from the *cellular* portion of the stem or branches, on which the function of extending the growth of the individual seems especially imposed. They may be distinctly traced, in young branches, to the pith; and where this has dried up, they may be seen to arise from the medullary rays. Sometimes they are stunted in their growth, and instead of being developed into branches, they remain as *thorns;* which are neither more nor less than short pointed branches, containing much dense woody structure (by which they are rendered extremely strong), and being destitute of leaves. Any one may satisfy himself of this, by looking at the common Black-thorn, in which many intermediate conditions may be seen. Now under cultivation, these undeveloped buds may be caused to become fertile branches; and this is another of the modes in which, in Linnæus's phrase, "wild fruits" may be "tamed." (§. 236.) There are no thorns stronger than those of the Acacia tribe, which are sometimes 5 or 6 inches long, formed with great regularity, and strong in proportion. The plants which bear them are often encouraged to grow in the East, for the purpose of forming hedges, which serve most effectually to keep out intruders, unless these are covered with some almost impenetrable envelope.

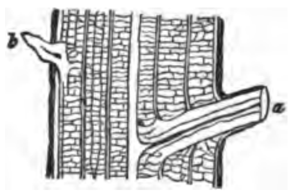

FIG. 76.—ORIGIN OF BRANCHES , branch originating in the first year, direct from the pith; *b*, a bud originating from the cellular portion of the third woody layer.

308. The influence of light upon the green colour of the leaves is remarkably shown, when the buds are unfolding. The stronger the sunshine, the sooner will they assume their characteristic hue; and, on the other hand, in dark dull weather they will remain for days together, almost of the same colour as

before they expanded. The following is an example of this fact, more remarkable than is ever seen in this country. "It frequently happens in America, that clouds and rain obscure the atmosphere for several days together; and that, during this time, the buds of entire forests expand themselves into leaves. These leaves assume a pallid hue until the sun appears; when, within the short period of six hours of a clear sky and bright sunshine, their colour is changed to a beautiful green." One writer mentions a forest on which the sun had not shone for twenty days. "The leaves during this period were expanded to their full size, but were *almost white*. One forenoon, the sun began to shine in full brightness; the colour of the forest absolutely changed so fast, that we could perceive its progress. By the middle of the afternoon, the whole of this extensive forest, many miles in length, presented its usual summer dress."

309. The influence of light is also shown, in modifying the direction of the stem. Where a plant sends forth a single stem or shoot, it will always direct itself towards the light; and this is especially manifested, where the light comes in only one direction, as when a Potato, which has begun to grow in a cellar, sends a shoot of several feet in length towards any aperture, through which even a small quantity of light finds admission. The reason obviously is, that, in consequence of the loss of fluid from the tissue of the stem, on the side on which the light falls, it is contracted, whilst that of the other side remains turgid with fluid; the stem makes a bend, therefore, until its growing point becomes opposite to the light, and then increases in that direction. Should any obstacle divert it, the same cause will bring it back.

310. The direction of the branches of trees growing in open spaces, is less influenced by light; since the rays of the sun exert a much inferior power in this respect, when they are reflected from clouds and other objects, so as to form what is commonly termed "diffused daylight." It is a curious fact, however, that there seems a tendency in almost every growing tree, to send its principal trunk directly upwards. Experiments have been made for the purpose of changing this. For instance, the stem has been bent much out of the perpendicular, by means of a rope

tied round its summit, and has been kept so for a long period. The plant would then push up *that* one of the side-shoots, which is most nearly in the line of the trunk; and this, increasing in length and diameter in successive years, will gradually present more and more the appearance of a continuation of the lower part of the stem; whilst that which was bent down, presents the aspect of a branch.

311. The same means is adopted, to repair a natural injury. Thus, the upper half of a large elm tree, which had a long straight trunk, the lower half being without branches, was broken off by a violent gust of wind. From the complete absence of leaves in the trunk that remained, it was not expected to survive; but, being in full sap at the time, the abundant nourishment it contained, occasioned the development of buds which were previously inactive; and a great number of small branches soon issued from the stump. Of these, the upper ones have grown most rapidly; and the two highest, which were at first nearly horizontal, have gradually changed their direction, so as to follow the line of the upright stem; and it now seems as if the trunk had originally divided, at that point, into two minor ones,—so completely has all appearance of the accident been lost.

312. The leaves of all plants have a very limited term of existence. In temperate climates, most trees shed them during the autumn, and pass the winter in a state of complete inactivity. Before they fall off, the leaves usually change colour,—sometimes very decidedly, as do those of the Beech; and it has been ascertained that at this period they absorb more oxygen, and give out more carbonic acid, which indicates their commencing decay. This absorption of oxygen has been shown, by experiment, to be the immediate cause of the change of colour; since the green matter of leaves, when acted on by substances which readily yield oxygen, is found to exhibit it. The separation of the leaf from the stem, is probably due to several causes. During the latter part of the summer, some of the vessels become choked up with solid matter; and those which proceed from the interior of the trunk, are overstrained by the addition to its diameter which has taken place, so that they are easily ruptured. The

tissues of the leaf itself, too, are gradually dried up; and the whole structure loses its vitality, and is cast off, as a dead part is from the body of an animal.

313. Trees and shrubs, which are spoken of as evergreens, do not really retain their leaves for more than a year; but they are not cast off until a new crop appears; and the exchange does not take place suddenly but gradually, so that the aspect of the tree never undergoes much alteration. In evergreens, the functions of the leaves are carried on, though with great languor, during winter; but at other parts of the year they are less active than those of the species which lose their leaves in autumn. There are some trees of tropical climates, which completely lose their leaves two or three times in every year, appearing as bare as in winter; and these are speedily replaced by a new crop. It is probable (though it has not been certainly ascertained) that in such trees, a new woody layer would be formed by every crop of leaves. In very hot and dry summers of this country, trees have been completely stripped of their foliage early in July, and have had strength to put forth a new and apparently vigorous crop of leaves. Such an effort, however, appears very exhausting to the tree, which is seldom so vigorous the next year.

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314. The facts stated in this chapter, respecting the influence of Vegetation on the surrounding air, are very interesting in connection with a plan which has recently been practised with much advantage, of growing plants under glass cases very nearly closed. They are constructed of almost any form or size;—the experiment will answer with a chamber of a foot in each direction, or in one as large as a common green-house. The plants to be reared are placed in a kind of trough, with a sufficient quantity of light earth and water; and the glass cover is then fitted upon this in such a manner, as not to be quite air-tight, but to allow of extremely little communication between the interior and the surrounding air. The advantage of this system is, that the plants are kept in an atmosphere thoroughly saturated with moisture; and that they can obtain the necessary supply of car-

bonic acid (which finds its way through the crevices beneath the glass cover), without being also exposed to the impurities which the atmosphere contains. In London and other large towns, the air is loaded with particles of soot and dust, which are so injurious to vegetation, that none but the most hardy plants will flourish there without some protection; yet under this system, the most delicate and beautiful plants may be reared, provided they are sufficiently supplied with light and warmth. Again, many plants are killed by exposure to the sea-air during long voyages; this being loaded with particles of salt. But under this protection, plants have been successfully transported to England from the most distant quarters of the globe, which could only be previously introduced by seeds. By the adoption of this plan, many who take an interest in the cultivation of plants too delicate for our own climate, may indulge their taste at a small expense. A window should be selected with a southern aspect, or nearly so, and a second pair of sashes should be fixed at the distance of a foot or 18 inches within or outside the first, as may be most convenient,—the fitting of the whole being as tight as possible, consistently with the easy movement of the inner sashes. In the space at the bottom, a trough is placed containing moistened earth; and the plants grown in it should be so trained, as to expose the surface of their leaves to the light as freely as possible. If a winter warmth is required, the window of a sitting-room in which a fire is constantly maintained, should be selected; and this will suffice to grow many plants which naturally inhabit the warmer regions of the globe. This method is particularly adapted for the growth of Ferns. The public are indebted for this important system, to Mr. N. B. Ward, of London.

CHAPTER IX.

GENERAL REVIEW OF THE NUTRITIVE PROCESSES IN PLANTS.

315. The functions of the several organs concerned in the Nutrition and Growth of the plant, having now been separately described, it next becomes desirable to take a general review of the whole; and to trace the connection between their respective actions, and to point out their bearing on the object of the whole of this beautifully-arranged system. When we look at a well-ordered household, we observe that the actions and duties of each member of it are planned and arranged by the heads of the family, so as to accord with their respective qualifications, and at the same time to conduce to the comfort and happiness of the whole; and the more completely this is accomplished, the greater is the harmony and regularity with which the labours of the whole are performed,—the less is the liability to interruption, arising either from the caprice or incapacity of any of the labourers. And in proportion to the completeness with which this end is gained, do we think highly of the wisdom of those who have studied and executed the means of attaining it.

316. Now the economy* of the Vegetable is precisely analogous to that of such a household. The whole structure is composed of a number of different *organs* or members, having different parts to perform in the general scheme; and these parts or *functions* are so beautifully adjusted together, that, in every variety of circumstances in which the being is liable to be placed, they shall still be executed in harmony, and with one common purpose. Thus we have seen that one organ pumps up the required

* This word literally signifies *household-law*; and in this sense it is applied in physiology, to designate the regular harmonious system, on which the actions of living plants and animals are performed.

water, another carries it, another uses it in cooking, another gets rid of the waste, another obtains the solid food, another carries the cooked provisions to all parts of the structure, another stores up the superfluity, another builds additions to the edifice, whilst another prepares to send out a colony, furnished with supplies of food, and with everything requisite to begin life for themselves. Now we have considered the separate parts of the establishment —we have inspected the pump, the conduits, the kitchen, &c.; the general economy of the whole remains to be reviewed. And if we have seen a Wise Design in those, our ideas will be still further elevated by this mode of viewing the subject.

317. We have seen that the fluid absorbed by Plants consists of water, in which are contained carbonic acid and ammonia; and in which are also dissolved the various mineral substances, which each species requires for its healthy existence, but which contribute nothing to the formation of those peculiar organic substances, that compose the vegetable tissues. The conversion of these elements into the substances intended for the nourishment of the plant, begins very low in the stem; and the proportion of them increases as it ascends. The substances at first produced are *gum* and *sugar*, which are the simplest in their chemical nature of all organic compounds; being made up of oxygen and hydrogen, in the same proportion as water contains, with the addition of carbon. Being nearer inorganic bodies in their composition, and in the tendency of the latter to the crystalline form, they are also nearer in properties; for they may be preserved for years in a dry state, without any impairment of their characters; since their tendency to spontaneous decomposition is not greater than that of many mineral substances.

318. The crude sap, immediately that it has been absorbed, b gins to mix with the matter which has been stored up from the previous year, in the tubes and vessels through which it rises; and in proportion as it ascends the stem, it dissolves more and more of this, so as gradually to present in taste, odour, &c., the peculiar characters of the plant itself. One object of this admixture has been already stated (§. 119); but some other is not improbably answered by it.

319. Although the peculiar characters of the proper juices of the tree are thus communicated to the ascending sap, yet they are possessed by it in but a very slight degree; and it is in consequence of this, that the ascending sap of all trees possesses very nearly the same properties;—as is shown by more than one curious fact. There are some plants which have not the power of forming true roots for themselves, and which obtain their supply of sap from the stems of trees to which they attach themselves. Such is the common Misseltoe. The seeds of this plant are deposited by birds on the exterior of the stems and branches of trees; and the root-fibres which they put out, insinuate themselves through the crevices of the bark, and incorporate themselves with the wood.

320. Now the Misseltoe imbibes the *ascending* sap from the wood of the tree or *stock* on which it grows; and this it converts into a proper juice, adapted to nourish its own structure, by means of its own leaves. The ascending sap of most trees being nearly alike, the Misseltoe seems to grow with almost equal facility on a great variety. It is remarkable, however, that it is very rare on the oak; and it is perhaps this circumstance which caused the plant, when found in connection with that tree, to be regarded by the ancient Druids in a religious light. Perhaps it is the *tannin* produced by the oak,—of which a small portion will be contained in the ascending sap, and which has been already spoken of as exerting a prejudicial influence on the vegetation of most other species (§. 209),—which is unfavourable to the growth also of the Misseltoe.

321. Now it is a very curious fact, that the law of growth of these root-fibres is different from that which governs other roots. For whilst the latter grow downwards towards the centre of the earth, these grow towards the centre of the bough or stem into which they may be penetrating. This tendency was ascertained by the experiments of the French physiologist Dutrochet, who caused a seed of Misseltoe to germinate, when hung by a thread near a large ball of metal; and he found that the radicle always directed itself towards the centre of this ball, near whatever part of the surface it might be placed. By this curious

adaptation, the Misseltoe, which, from the want of power to form perfect roots, would otherwise be unable to exist, is endowed with a compensating power;—it being as much a part of its natural habits to grow upon the stem and branches of trees, as it is for other plants to send their roots down into the ground.

322. The fibres of the Misseltoe seem to incorporate themselves completely with those of the stock; and so intimate is the connection between them, that coloured fluids will pass from the stem into this *natural graft*,—for so it may be termed. It does not appear, however, that any communication exists between the parasite and the *bark* beneath it, which is always found to be in a dead state around its insertion. But if the part of the branch at which it penetrates be divided with a saw, it will be seen that the two *woods* are so thoroughly united, that the line of separation between them can scarcely be traced. That the Misseltoe is itself quite deficient in the power of absorbing fluid, has been clearly proved by experiment. If the stem of this plant be cut off and immersed in water, it will absorb little or none of the fluid; whilst, if a portion of the branch with which it is connected be cut off and immersed in a similar manner, it will absorb nearly as much as if furnished with leaves of its own.

323. A curious fact illustrative of the great difference in the characters of the ascending and descending sap, is that the former is nearly or quite harmless in those plants whose proper juices have the most virulent properties. Thus, the inhabitants of the Canary islands draw off the former, which serves as a refreshing drink, from the interior of the stem of the *Euphorbia canariensis;* a tree of which the descending sap is of a very acrid nature, resembling that of the common Spurge of this country, but much more powerful.

324. The conversion of the water and carbonic acid absorbed by the roots into gum or sugar, involves the setting free a portion of the oxygen contained in those compounds; for as water is composed of oxygen and hydrogen, and carbonic acid of oxygen and carbon, it is evident that, in the production of any substances containing no very large proportion of oxygen combined with

carbon and hydrogen, there must be a superfluity of the first of these ingredients. This oxygen is probably conveyed away by the spiral vessels, which form the medullary sheath of Exogens, and which are diffused through the woody bundles of the stem of Endogens. These spiral vessels communicate with the leaves; and through them, the oxygen is given off to the atmosphere. By dividing stems under the surface of mercury,* and collecting the minute bubbles of gas which arise from the cut ends of the spiral vessels, it has been shown, that they contain a considerably greater proportion of oxygen than exists in the atmosphere.

325. The processes by which the crude sap conveyed to the leaves, is converted into the "proper juice" of the plant, have already been described in so much detail, that it is not necessary to do more than briefly recapitulate them here. By Exhalation and Evaporation, a great quantity of superfluous water is got rid of; and the fluid is thus concentrated. By the absorption of carbon under the influence of light,—the process to which the name of *Digestion* may be given,—a large quantity of solid matter is added to it; and the materials are afforded for the increase of the woody structure, which requires this ingredient in a peculiar degree. And by the process of Respiration is removed the product of the slow decay of the whole structure, which would be highly injurious if retained within it.

326. We must remember, however, that, in speaking of these functions, we only state the *evident results* of those more obscure changes, which take place in the interior of the plant, and of which the nature is still unknown. In all plants, the functions of Exhalation, Digestion, and Respiration, are performed almost in a similar manner; and the materials upon which they operate are (as already explained) nearly of a similar character; and yet the products are remarkably different. In nearly all of them, however, the material of the tissues themselves is the same. Woody fibre, for example, is found by the chemist to be com-

* This fluid is used instead of water, when it is desired to collect gases which might be absorbed by water. (See Treatise on CHEMISTRY.) In the present case it is employed to prevent any carbonic acid that might exist in the vessels, from being undiscovered, through the absorption of it by the water.

posed of the same elements, in the same proportions, from whatever tree it is taken, provided it be cleared from those substances which are deposited within it, for the purpose of affording it additional strength. But when we look at the immense variety of products which the Vegetable kingdom supplies, varying no less in properties than in appearance, we are lost in wonder at the marvellous nature of those processes, in which a difference, undiscoverable by all our most refined means of research, shall be productive of such a number of widely-different results. And at the same time the reflecting mind cannot forget, that these results are all of a kind most valuable to Man, furnishing him with the necessaries, the comforts, and the luxuries of life,—support in health, medicine in disease, and the materials of great part of his clothing, his books, and various articles which minister to his mental and moral improvement.

327. These substances may be distinguished under two classes; the *nutritive products*, adapted to supply the materials of increase to the tissues themselves;—and the *special secretions*, which are for the most part contained or stored up in them. The former are common to all plants; of the latter different kinds exist in the various tribes.

328. Of the nutritive products, which are carried by the descending sap to all parts of the structure, (as are those of a similar nature contained in the blood of animals,) the principal is *Gum*. This is found in the bark and wood of all plants; and is present in such abundance in several, which are called Gum-trees, as to flow in plenty from the bark when wounded, or when its surface cracks. Of these trees, most belong to the Acacia tribe; and it is in warm climates only, that the formation of this product is so abundant, as to make the collection of it desirable. Various modifications of this principle exist in different vegetables; but they may all be regarded as combinations of pure gum with other substances. Gum Arabic is one of its simplest forms; this is really brought from Arabia, where it is annually collected in the Acacia forests, at the end of November. A large quantity is imported into this country, on account of its extensive use in calico-printing and other arts. It is a highly nutritious

substance to man and animals; and it forms an important article of diet in Arabia and Senegal. Those who are engaged in collecting it live for a time almost entirely upon it; and six ounces have proved sufficient to support an adult for 24 hours. It is on record that a caravan crossing the Desert, their provisions being exhausted, preserved themselves from famine, by eating the Gum Arabic, which formed part of the merchandise they were transporting. But no animals could continue long to subsist on this ingredient alone; since it contains no nitrogen, which is still more essential to *their* support, than to that of plants. (See Anim. Physiol. §. 155—157.)

329. Gum is almost the only organic substance, that seems to be immediately applied to the nutrition of the plant, when absorbed from without, instead of being first decomposed into water and carbonic acid; for a plant thrives well in a solution of it. This is evidently, because it thus supplies an important ingredient in the ascending sap, in which it would otherwise have to be formed. (§. 317.) The gum contained in the elaborated sap appears to have undergone some change, which renders it more prepared for beiug converted into an organised tissue. It is this, which, being poured out between the bark and the newest layer of wood, is the viscid substance termed *cambium;* in which the rudiments of the cellular tissue, that is to form part of the new layer of wood, after a time present themselves. Even if this cambium be drawn off from the stem, its particles show a tendency to arrange themselves in a form resembling that of cells and vessels; though no perfect tissues are produced by this kind of coagulation. The interior of young seeds is filled with a glutinous pulpy fluid of a similar description; and partitions gradually appear in this, converting it into a mass of cellular tissue. Ordinary Gum may be considered as having the same character in the Plant, as Albumen possesses in the Animal; being the raw material, at the expense of which the tissues are ultimately formed. But this peculiar organisable Gum is evidently analogous, in its tendency to become organised, to the Fibrin of Animal fluids. (Anim. Physiol. §. 16—19.)

330. If a wound be made in the bark, a similar glutinous

exudation is thrown out from the cut edges; and by the conversion of this into solid tissue, the wound is gradually healed. If a complete ring be cut away from the bark, this exudation will be much the greatest on the *upper* side,—showing that it comes from the *descending* sap; but it is not altogether confined to that edge, since a portion of the descending current, having been carried by the medullary rays into the interior of the stem, is not checked by this interruption to its flow through the bark. Thus we perceive that, although there is not in Plants, as in Animals, a regular continuous circulation of nutritious fluid,—that which has once passed through the system of the latter, being impelled again through its vessels, after having undergone the necessary purification,—Nature has provided for the reparation of their wounds in the most advantageous manner.

331. From this form of Gum it would appear, that the materials of the tissues are produced; but those by which woody fibre is consolidated, are not the same in chemical constitution, containing a larger proportion of carbon. And thus we see why it should be peculiarly necessary for the production of firm wood, that the leaves should be exposed to the full influence of light, by which alone the proper amount of carbon can be introduced into the system. As already stated, whilst cellular tissue increases in every direction, woody fibres seem to grow almost exclusively downwards. They may be traced gradually descending from the leaves, in which they always originate, just as the roots make their way through the earth. They pass down in the space between the bark and wood, at the time the cambium is there; and this fluid probably contains the materials for both tissues. If an obstacle intervene,—as, for example, a branch passing off from the stem,—they do not stop in consequence of it; but they separate to one side and the other, and re-unite below, just as a bundle of roots would have done. These fibres, being intermixed with the cellular tissue produced by the cambium, compose the new layers of wood and bark, of which a new one is formed every year; and it is in this way, that those additions are made to the quantity of solid matter contained in the stem, which the supply of descending sap is principally intended to furnish.

332. The production of new buds is accomplished, as already stated, by the cellular tissue alone; and as they are connected more or less closely with the medullary rays, it is easy to understand, how they derive their nutriment from the descending current. Nothing but cellular tissue exists in them, until they have expanded themselves into true leaves, and then they form the materials of woody fibre for themselves. The same is the case with flower-buds, seeds, and other young parts.

333. Although *Gum* sems to be the chief nutritious product of the assimilation, by the plant, of the substances which formed its aliment, it is not the only one. *Sugar* in many cases appears to have the same office, especially in young and rapidly-growing parts. Thus, the starch of seeds is converted into sugar in the first stage of their growth (§. 283); and the sugar is dissolved by the water around, and carried up the young stem to the leaves. The starch existing in the disk of flowers, again, is converted into sugar, for the nourishment of the young seeds; and it is the superfluous portion of this, which flows off in the form of honey. There are particular plants, which contain a very large proportion of sugar, just as we have noticed others which abound in gum. Such are the Sugar-cane, the Beet-root, and the Maple. The sweet juice which abounds in the Sugar-cane is exhausted by flowering; and appears, therefore, destined for the development of the set of organs concerned in that process. The same is the case with the Beet-root, and also in the Maple; in the former, the sweet juice does not begin to accumulate in the roots, until the development of the growing parts has ceased for that year; in the latter, the juice which was previously sweet, ceases to be so, whilst the tree is putting forth its buds, leaves, and blossoms; in both these instances, the use of the sugar in the vegetable economy is clearly seen.

334. Of the importance of Sugar as an article of commerce little need be said. The annual production in different parts of the world, is estimated at not far from 20 million hundred-weights, or a million of tons; and this is nearly all obtained from a single kind of plant,—the Sugar-cane. The soft spongy tissue of this plant, previously to its maturity, contains a large quantity of a

sweet juice, which is pressed out from the stems by passing them between rollers. This juice is boiled down into a thick syrup, which crystallises, and deposits the sugar it contains. This is what is commonly known as *brown* sugar; and it has to undergo a subsequent process of refining, in order to convert it into *white*. In Canada and other parts of North America, a good sugar is produced from the Maple, by tapping the stem when the sap begins to arise in the spring; the quantity of sugar obtained, by boiling the sap that flows from one tree during a period of six weeks, is sometimes as much as 30 lbs.

335. It is not unfrequently necessary, that a store of nutritive matter, which may be required at some future time, should be provided in the Vegetable system; in such a situation, that it shall be out of the general current of the circulation, and at the same time easily brought into it. In Animals, the *fat* constitutes a store of this kind. The superfluous nutriment introduced into their system is converted into this substance; which, besides other purposes that it serves, is ready for the support of the body, when from any cause there is a failure of the supply, on which the animal usually depends. In some animals, this production of fat takes place at regular periods; thus Bears, which pass nearly the whole winter in sleep, and take little food during that season, become very plump in the autumn, and are observed to be very lean soon after they have emerged from their winter retreat.

336. Now the *Starch*, which is found so abundantly in many Plants, and in some part of almost every one, serves the same purpose as fat. It is a gum, slightly altered, and inclosed, as it were, in a series of minute bags, which fill the cells of cellular tissue, and receive the form of these. Starch, when removed from the plant, exists in the form of minute granules; each of which, when examined with the microscope, is found to consist of a series of layers of a half-fluid substance, the interior ones being nearly fluid like dissolved gum, and those on the outside being almost as firm as membrane. When put into cold water, they retain their structure, as the outside layer is not acted on by that fluid; but when exposed to a heat of about 160°, this

little sac bursts, and its contents are set free and dissolved in the water; and this is why starch, once dissolved in hot water, can never be restored to its original form.

337. Thus, then, we may consider Starch as little else than Gum, divided into minute portions, and stored up out of the way of the nutrient fluid, which would otherwise dissolve it whilst circulating. In all instances, the stores of this substance appear destined for the nourishment of young parts; since they are found in the neighbourhood of these, and are exhausted by their growth. Thus, starch forms a large part of the substance of all seeds; sometimes (as in the Corn grains) being deposited *around* the germ of the young plant; and in other cases (as in the Pea and Bean) being included *within* it, forming a great part of large fleshy cotyledons or seed-leaves, which first come to the surface after the seed has begun to sprout, and which wither in proportion as the young plant develops itself. Starch is found abundantly, again, in the fleshy underground stems destined to nourish young shoots, as the tubers of the Potato, and the rhizoma of the Arrow-root; and it has been lately pointed out that, if the blossoms be pulled off the plants before opening, the accumulation of starch will be much greater, in consequence of the exhaustion of the store having been prevented. Starch is also abundant in the fleshy roots which have to furnish nutriment to the young stems, when they first begin to grow; as in the Briony and Elecampane. It is also found in the pith and bark of many Exogens, and in the cellular tissue occupying the centre of the stem of many Endogens (such as the Sago Palm), where it forms a reservoir of nutriment for the young leaves.

338. The deposits of starch generally continues to increase, so long as the plant which forms it is in active vegetation. It then arrives at its greatest amount, and remains the same until the young parts which are to be supplied from it have begun to grow; and then it rapidly diminishes. Thus, it has been stated that a hundred pounds of potatoes contain of starch,

In August	10 lbs.	In March	17 lbs.
September	14½ lbs.	April	13¾ lbs.
November	17 lbs.	May	10 lbs.

339. Although this deposition of starch fulfils a part so evidently important in the vegetable economy, we cannot doubt the wise and benevolent intention of the Creator, in thus providing a store of nutritious and palatable food for Man, in situations in which he can so easily obtain it; and it is interesting to remark that, from the completely separate form in which it exists, it may be obtained in a state of purity from many vegetables, which, as a whole, are of very poisonous character. An illustration of this fact occurs in the Cassava, which forms a most important article of food in almost all the warmer regions of the globe. This substance is the starch contained in the root of a plant termed *Jatropha Manihot*; and the root contains also a juice so poisonous, that it is employed by some of the savages among whom this plant abounds, to tip their arrows and spears. The root is usually ground or rasped into a sort of coarse meal; and from this, when put under pressure, the juice runs off, leaving the starch nearly pure. The *Tapioca* of Brazil is nearly the same with Cassava.

340. Starch cannot be applied to the nutrition of the tissues, however, without undergoing an important change, which reduces it, in fact, to the condition of sugar or gum. Of this change there are many instances in the progress of vegetation. That which is best known, is the conversion of the starch of seeds into sugar, which takes place during germination; and upon this the process of *malting* is founded. The grain of barley contains a large quantity of starch; but, when the embryo is made to sprout, this starch is converted into sugar for its nourishment. Now the germination of the seed is caused, by steeping it in water, and then placing it in a warm atmosphere; and this is the first stage of the process of malting. As soon, however, as the growth of the embryo has proceeded far enough, for the proper quantity of the starch to be converted into sugar (which is known by the length of the young root, and by the appearance of the grain itself), the germination is checked by the application of a higher degree of heat, which kills the young plant; and the newly-formed sugar can then be employed, to give sweetness to water or other fluids. In the same manner,

the starch of Potatoes and other tubers, is converted, when required for the nourishment of the growing buds, into sugar, which is absorbed by their vessels; and nearly the same may probably be said of every other instance, in which starch is laid up for a purpose of this kind.

341. Now this change of starch into sugar is one of a purely chemical nature; for it can be performed in the laboratory of the chemist, by pouring hot water on the starch, so as to break the vesicles and set free the contained gum; and then treating this with a weak acid for some time; by which the whole is converted into a sugar, that scarcely differs from that of other kinds. In the Vegetable economy, however, this change is effected by another means. In the juices of the plants themselves, there is a substance termed *diastase;* very minute quantities of which, have the remarkable property of changing starch into sugar. This diastase exists in seeds, and is found in larger quantities near the *eyes* or young buds of the Potato, by the vessels of which it is carried through the mass of starch when required. How beautiful an arrangement it is, that a substance possessed of the remarkable property of converting starch into sugar, should be formed, wherever a store of the first of these substances is laid up, for the purpose of affording a supply of the second when required,—and that this *diastase* should be found nowhere else, than in the very parts of the vegetable structure, in which it will be of use!

342. We see, then, that the form in which nourishment is conveyed to the growing parts of plants, is that of *gum* or *sugar*. These two substances are composed of the same elements, in nearly the same proportion; and the former may be changed into the latter. They are usually found together in the *cambium* (§. 329), which is destined to be gradually organised, or converted into tissue; and also in that thick mucilaginous* fluid, which forms the pulp of the very young seeds, that exist in the seed-vessel before the flower has fully expanded. The gumminess of this fluid is at once perceived by its glutinous properties; and that it contains sugar, is known by the sweetness of

* Mucilage is the term applied to a solution of gum in water.

its taste. Gum and Sugar, therefore, are to be considered as the materials, out of which the Vegetable tissues are constructed; and Starch must be converted into one of these, before it can be applied to a similar purpose.

343. Now the proper juice elaborated by the leaves of one plant, may sometimes serve for the nourishment of another. A group of parasites, which, having leaves of their own, can elaborate for themselves the crude sap they obtain from the roots of another tree, has been already described (§. 320); but there is another, which is destitute of leaves as well as of roots, and which is therefore dependent for support, on the elaborated sap of the plants, to which its different kinds respectively attach themselves. And as the nature of the proper juice of each species varies much more, than does that of the crude sap, these parasites cannot subsist upon the fluids of many different species, but are for the most part restricted to those of a few. Most of them grow upon the roots or underground stems of others; no part of them appearing above the surface (in general at least), except the flower-stalks which are occasionally sent up. They abstract the nutritious fluid from the plants to which they cling, by means of a number of little suckers, which are formed upon their roots, and which fix themselves to the bark of the stem and roots; and in this manner, they not unfrequently cause the death of the plant, by drawing off its juices.

344. One of the commonest kinds is the *Orobanche*, or Broomrape, so named from the ravages it is thought to commit on the Broom and Gorse of our heaths. The different species of this plant infest different kinds of vegetables; thus one infests broom and furze; and in many parts of Flanders, the farmers are altogether deterred from the cultivation of clover by another species, of which the seeds lie dormant in the soil, until it is made to support plants upon which the parasite can grow, and which it then attacks vigorously. Another species of this genus confines itself to certain Composite flowers, as the Knapweed; one is found exclusively upon the roots of Hemp, and another upon those of Ivy. The *Cuscuta*, or Dodder, is another plant of the same description, which attaches itself to the stems of the

nettle, clover, and other plants, round which it coils in a direction contrary to that of the sun. When luxuriant, the Dodder gives a strange appearance to the herbs and bushes on which it grows, covering them, as it were, with a veil of reddish, leafless stalks, studded with blossoms. Their seeds, unlike those of most other parasitic plants, germinate in ordinary soil; but if the seedlings be kept there, they will soon wither and die, from the want of their peculiar nutriment. Some parasitic species derive a part of their aliment, in their adult condition, from true roots spread through the soil; but are still dependent for most of the solid matter they require, upon the supply of ready-elaborated sap, which they obtain by their suckers from the plants, upon whose bark they fix them.

345. From these naturally parasitic plants, we may pass to those, which are rendered so by artificial means. It will be hereafter explained (Chap. XII.), that the cultivated *varieties* of plants cannot be propagated with any certainty by seeds, from which we are only sure of obtaining new plants of the same *species* (§. 15). Thus, the seeds of a Golden Pippin or of a Russet, sown in different soils, will all produce plants bearing Apples of some sort; but these are not likely to bear any greater resemblance to the parent, or to each other, than all Apple-trees have to their kind; and the character of their fruit will be quite uncertain,—it being little better, if the soil be poor, than that of the Crab, from which all the varieties of Apple have originated.

346. In order to propagate any particular variety of fruit or flower, the cultivator reserves some of the leafy buds of the tree or plant, and places these in circumstances favourable to their growth. In many instances, the leaves or leaf-buds have the power of forming roots for themselves; and this is especially the case, when the neighbouring part contains a temporary supply of nourishment for them, such as the tuber of the potato imparts to the *eyes* or buds it contains. Thus, if the young branches of a Vine be cut into as many pieces as there are leaf-buds, and these be properly laid in a favourable soil, and stimulated to growth by heat and moisture, they will soon put out roots and become perfect plants; being at first supported by the nutritious

matter contained in the wood to which they adhere, and afterwards by the products of its decay. It is in this way, that the Sugar-cane is propagated,—the plants that spring from these cuttings being more vigorous, and coming earlier to maturity, than those raised from seed. This method is often employed by the Gardener; who sometimes varies it, by not detaching the bud from the parent stock, but by bending a branch into the earth, and letting it be partly supported by the juices of its parent, until it has put forth roots for itself. This is termed, propagating by *layers*.

347. But there are many cases, in which it is desirable not to trust to the power which the bud may possess, of forming roots for itself; and advantage is then taken of the tendency, which the growing parts of plants have, to adhere and become united to each other. Such adhesions not unfrequently take place from natural causes. Thus, if two branches, either of the same or of different trees, be lying across each other, in such a position as to rub against one another when moved by the wind, the bark will be worn off from each, and a fluid will be exuded from the wounds, which will be in time converted into solid tissue. This tissue is capable of conveying sap from one branch to the other; for a tree that has been thus united (for the sake of experiment) to two others, and has been then cut off from all communication with the soil, has continued to live, without any other supply, than that which it derived through these trees. This natural adhesion of vegetable tissue is well seen in the ivy; the branches of which often interlace and graft together in various places, until the whole forms a rude network, inclosing the trunk of the tree on which it has climbed.

348. Now the gardener imitates this process, when he wishes to supply the separated buds of a tree or plant, which he desires to propagate rapidly, with nourishment ready to be elaborated by its leaves. He chooses a *stock*, or stem deprived of its own buds, and cuts off its top in a sloping direction, so as to expose a large surface of wood and bark. He cuts the lower end of the young branch, termed the *graft*, in a similar manner, and then fixes them together; taking especial care that the bark and wood

of the one, should meet and join with the bark and wood of the other. If the operation succeeds, the stock and the graft become so completely united together, as to form in time but one tree, in which all mark of the original separation has disappeared. The stock draws up from the soil the fluid, which the leaves of the graft require; these obtain carbon from the air, and elaborate the crude sap into proper juice, a portion of which is supplied by the graft to the stock for the extension of its own tissues, just as if the stem really belonged to it.

349. To effect this object, it is generally necessary to choose as the stock, a plant either of the same species with the graft, or one very closely allied to it; and the less the relationship, the more care and precaution must be taken to secure a union, by bringing the newest layers of bark and wood into contact. It is customary to select for the purpose, some less valuable form of the same species; thus the cultivated varieties of Pears and Apples are grafted upon the Wild Pear and Crab. Or a species nearly allied will sometimes answer almost as well, and, from being readily procured, is commonly employed; thus, Peaches and Apricots are grafted on the common Plum. The operation does not always succeed, between two species of different genera; and it fails entirely, if an attempt is made to unite individuals of different families. Thus, for example, Pears answer well upon Pears, nearly as well upon Quinces, less freely upon Apples or Thorns, and not at all upon Plums or Cherries, which are of a different family. The Lilac will take upon the Ash, notwithstanding their great apparent difference, because they are of the same natural family; but the Olive, which also belongs to the same family, cannot be profitably grafted upon the Ash, since the vegetation of these is too different, to allow them to live long together.

350. From what has been said regarding the readiness of the Misseltoe (which may be considered as a *natural graft*), to grow upon various kinds of trees, and the great similarity of the ascending sap in most of these, it is evident that the cause, which thus restrains the gardener in the choice of his stock, is not merely the difference in the properties of the fluids of the

two kinds, but also the difference in the general character of their growth. It is essential, that the stock and graft should be naturally in sap at the same time; and this is more likely to be the case in nearly allied species than in others. However, in very succulent plants, such as the Cacti, of which the fleshy stems are always full of fluid, grafts of very different species succeed well together; and this exception helps to prove the rule. It is necessary, also, that the rate of growth of the two should be nearly the same; for, if the graft be of more rapid growth than the stock, and more be sent down to the latter than it can convert into tissue, a swelling will be formed above the line of union, like that which takes place when a cord is bound round a stem (§. 144); and this will increase, so as in time to cause the death of both parts, by altogether obstructing the passage of fluid.

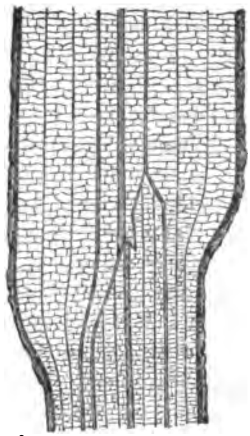

FIG. 77.
PERPENDICULAR SECTION OF A GRAFT INSERTED ON A DWARF STOCK.

351. Not only does the process of grafting enable the gardener to multiply with greater rapidity, and to preserve with more certainty, any valuable kinds of flower or fruit; but, by the judicious selection of a stock, a favourable influence may be produced upon them. Thus, the more delicate kinds of Vines produce larger and finer grapes, when worked upon coarser and more robust kinds; and the Double Yellow Rose, which seldom opens its flowers, and will not grow at all in many situations, blossoms abundantly, and grows freely, when grafted on the common China Rose. Some statements, however, which impute to the stock a much greater influence, are without any foundation in truth. Thus, it has been asserted that Roses become black, when grafted on Black Currants; and Oranges crimson, if grown upon the Pomegranate:—but this is altogether erroneous, as these species will not unite at all.

352. Errors in regard to the success of the process have arisen from an occurrence that sometimes takes place,—the formation, by the graft, of independent roots, which supply it partly or wholly with nourishment, with little or no assistance from the stock. In this way has been explained the fact, that the Olive has been made to grow upon the Fig tree (as recorded by Columella, one of the earliest writers upon Agriculture); for no proper union can take place between them, on account of the wide difference in their character. Mention is made by Pliny, of a tree in the garden of Lucullus, which was so grafted as to bear pears, apples, figs, plums, olives, almonds, grapes, &c.; and at the present time the gardeners of Italy sell plants of Jasmines, Roses, Honeysuckles, &c., all growing together from a stock of Orange, or Myrtle, or Pomegranate, on which they say they are grafted. But this is a mere cheat; the fact being, that the stock has its centre bored out, so as to be made into a hollow cylinder, through which the stems of Jasmines and other flexible plants are easily made to pass, their roots intermingling with those of the stock. After growing for a time, the increase in the diameter of the stems thus enclosed forces them together, and they assume all the appearances of being united. Such plants are, of course, very short-lived.

353. It may be useful here briefly to retrace the mode, in which the elaborated sap is prepared and circulated. The roots (or, failing them, the general surface of the plant, especially the leaves and young bark) absorb fluid, which consists of water, usually having some carbonic acid and ammonia diffused through it, and also containing a small proportion of earthy matter (§. 169). This fluid is conveyed to the leaves, in part by the attraction which they have for it, and in part by the propelling force of the roots (§. 116). Whilst ascending the stem, it is mixed with some of the fluid previously elaborated, and it undergoes some changes, in which oxygen is set free, and in which the quantity of gum and sugar contained in it is increased. In the leaves, a large quantity of superfluous fluid is parted with, by *exhalation* and simple *evaporation;* and a great deal of additional carbon is obtained by the green surfaces, from the carbonic acid

of the air, under the influence of sun-light; at the same time, a small quantity of carbonic acid is being constantly set free from the whole surface, by the process of *respiration*, oxygen being absorbed.

354. These are the principal changes which can be detected by the observer; but there must be others of a much more extraordinary nature, taking place within the vessels of the plant; by which, from the simple elements just enumerated, those peculiar substances are formed, which are to serve for the nutrition of the structure, or are to be laid up for some yet unknown purpose in its economy. Of the mode in which water and carbonic acid are changed into gum or sugar, the chemist is entirely ignorant; and although these are the most simple of all the extraordinary conversions, which take place in the assimilation of inorganic matter, he is completely unable to imitate it. There is reason to hope, however, that he will not long remain so; since some Animal compounds have been produced by artificial means.

355. A still greater mystery is the process, by which the elaborated sap is converted into cellular tissue, or any other form of vegetable structure. Some parts of this process have been observed, and will now be described; but of *the cause* of the changes, nothing is known. The young seed, before the flower has expanded, is filled with a sort of sweetish mucilage, which is partly composed of gum ready to become organised (§. 329). The first step consists in the appearance, in what was before a nearly transparent fluid, of a large number of very minute granules. Soon afterwards, larger granules appear, round which the smaller ones cluster; and they soon present a regular form, resembling that of pieces of money, being flattened and circular disks. On one surface of each of these, a delicate membrane is seen to project, just as a watch-glass projects from the face of a watch; and this membrane gradually extends much beyond the original disk, so as to form a kind of bag, in one wall of which that body is included. Still, the membrane is of so delicate a consistence, that it is easily dissolved away, by shaking the vessel in which the process is being observed; and it is not until

some time afterwards, that it acquires any considerable firmness. During the period of the formation of the cell, the space between the membrane and the original disk is filled with fluid; and in this, a regular circulation may be seen to take place,—several currents proceeding from the nucleus (or *cytoblast* as it is technically called), and returning to it again.

356. When the cell becomes mature, the original disk is usually absorbed, and no further movement of fluid is seen within the cavity; but there are some cells in which it always remains, appearing as a dark spot in their walls; and in these, the circulation of fluid generally continues. This circulation may be well seen in the beaded hairs of the *Tradescantia Virginica* (Virginian Spiderwort), which consists of several distinct cells; at the bottom of each of these, the disk or *nucleus* may be seen, and several currents may be observed to proceed from it and return to it again. It is a circulation of this kind, which has excited much attention in the stem and branches of the *Chara* (a little cryptogamic aquatic plant), which consist only of large cells laid end to end. The fluid passes down one side of the stem, and up the other, turning round at each extremity. If the stem (which is usually composed of a single cell, sometimes many inches long) have a thread tied round its centre, so as to separate the original cell into two, each of these will have a complete circulation of its own. A similar movement of fluid has been seen in the *Frog-bit* (another aquatic plant of this country), and in many others; and it is nearly certain that it takes place in every vegetable cell that exists, during some period of its growth; being only visible for a short time in some, which soon arrive at a condition little subject to change; but continuing during the greater part, or the whole of life, in others.

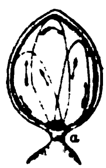

FIG. 78. CURRENTS IN THE HAIRS OF TRADESCANTIA.

357. This movement of fluid in the individual cells, is quite distinct from the general circulation which has been described in the higher plants. It is a part of the process of formation, by which the nutritious fluid that is brought to each part, is converted into organised tissue. In the simple Cellular plants, where

the same surface performs alike the functions of absorption, exhalation, digestion, and respiration, there is no general circulation of fluid; since each of the cells composing the whole structure, imbibes the materials of its nutriment for itself, and converts them into the substance of its own tissue, or employs them in the production of new cells. These seem to be usually developed from the fluid within the parent, in the same manner as the cells of the young seed are produced from the gummy matter it contains, as just now described; and the analogy is the more close, since the membrane lining the seed may be regarded as itself a single large vesicle. The increase in size of any organ, is occasioned in part by the enlargement of each individual cell, and in part by the development of new ones; which are formed in some instances between those previously existing, and in other cases (especially in the root) at the extremity only.

358. In the simplest Cellular plants, therefore, there is no necessity for any general circulation of fluid; and no other movement is seen but that which occurs in single cells. But in the more highly-organised tribes,—where the parts which receive the different kinds of food from the elements around, are at a distance from each other, and from those to which the nutritious fluid must be supplied,—a general circulation is required, to bring them all into connection; and this is accordingly found to exist, so that every part of the structure is nourished by a fluid, that has been elaborated by a system of organs, of which each is particularly adapted to a single object, whilst the actions of all are directed to a common purpose. This elaborated sap, being supplied to the growing parts of a plant, gives to them all the means of development that they can require; and they then only need the influence of light and heat, to perform their respective actions with vigour. These actions, however, are all performed, in the highest plant, as in the lowest, by *cells* alone;—the *vessels* serving merely as conduits for the passage of fluid;—and the woody fibres, where they do not assist in this office, being destined merely to give mechanical support to the fabric. It is by the cells of the spongioles, that the fluid taken in by the roots is absorbed; it is by the cells of the leaves and other green parts,

that carbon is fixed from the air;—these same cells are the instruments of the functions of exhalation and respiration, and of the final elaboration of the sap;—other cells, dispersed through various parts of the plant, have the office of secreting or separating from this some of its peculiar contents;—and lastly, it is by the action of cells (as we shall hereafter see, Chap. XII.), that the process of reproduction is carried on, in the highest, as in the lowest. Thus in regard to the actions of the cells, of which they are respectively composed, there is but little difference between the simplest and most complicated Vegetable structures; the distinction being chiefly in this,—that among the former, one cell may discharge *all* these offices; whilst in the latter, the several functions are performed by distinct cells, adapted to them alone.

CHAPTER X.

OF THE SECRETIONS OF PLANTS.

359. We have seen that the elaborated sap contains the materials of the various tissues of the Vegetable fabric; and an outline has just been given, of what is known of the mode, in which they are converted into living structure. The principal uses to Man of the various kinds of these structures, will be best stated, when the chief groups of plants are described, in the second division of this volume. We have next to consider a class of products, which are not of the same character; for they serve no obvious purpose in the nutrition of the plant itself, and are never converted (so far as can be ascertained) into the materials of its tissues. They usually make their appearance in the elaborated sap; but not unfrequently they are afterwards separated in some degree from it, and stored up (as it were) in a particular portion of the plant. In Animals we find a provision of a similar kind. The blood not only contains the elements of the solid tissues which are to be nourished by it, but also of fluid secretions, which are separated from it by special organs. Hence the term *secretion*, which means a separation or setting-apart, is derived.

360. In Animals, however, such secretions are usually destined to answer some obvious purpose, either in the system or out of it. Thus the secretion of saliva serves to moisten the food, and that of gastric juice to digest it; and in this process it is one function of the bile to assist. Again, the secretion of milk in the female for the nourishment of the young, that of poison in the venomous serpent for the destruction of its prey, that of the glutinous fluid with which the spider constructs its web, are instances of the separation of certain ingredients of the blood, which are

sent out of the body for particular objects. But Secretion in animals has other purposes;—namely, to purify the blood from certain ingredients, which, if they accumulated in it, would occasion disease and even death. This is the purpose of the separation of carbonic acid by the lungs; and also, in part, of the secretion of bile, which carries off a large quantity of the superfluous carbon of the system. In the same manner, the secretion of urine carries out the superfluous nitrogen, which exists very largely in this fluid. (See ANIM. PHYSIOL. Chap. VII.)

361. Now in regard to the Secretions of Plants, it is very remarkable that, whilst in number and variety they much exceed those of Animals, the use of them in the Vegetable economy should be much more obscure. In a few instances only are they destined to be sent out of the system; they are usually deposited in some part of it; yet they are not even separated in every instance, from the nutritious part of the juices, in which they are at first formed. The *Secretions* of plants comprehend all the *peculiar* products, which do not form part of their tissues; thus, all the vegetable dyes, the active medicinal principles, the oils, resins, &c., and the aromatic or volatile oils, belong to this class of products. Now as the substance of which the tissues of plants are composed, is everywhere almost the same, any varieties which these tissues may present, in colour, taste, &c., must be due to them; and it is from their presence, that each plant derives its particular character, either as an article of food, or as furnishing products useful in medicine or the arts. The pure vegetable tissue, and the nutritious gum or starch combined with it, are nearly tasteless; and the alburnum or sap-wood of trees possesses neither toughness nor colour. The former may be rendered uneatable, by the disagreeable taste or injurious nature of the secretions diffused through it; the latter is strengthened, and receives its peculiar colour, by the deposition in its cells and tubes, of products which have been separated from the circulating fluid, and which give to the wood a density proportionate to their amount, and to their own power of subsequently hardening.

362. The formation of these Secretions is still more dependent on the influence of *light*, than is that of the nutritive materials

themselves. Many plants, which, under the rays of a tropical sun, produce secretions of a powerful character, whether as medicines, as aromatics, or as dyes, are almost inert in colder climates, even when the amount of heat artificially given may fully equal that to which they have been accustomed. Thus, the Tobacco of Persia is universally celebrated for its peculiar perfume; and from the Roses of the South alone is it worth while attempting to obtain the powerful essential oil, which is known as Otto or Atar of Roses. This circumstance is taken advantage of in the growth of vegetables for the table; for, if they are reared under a diminished light, many kinds of plants may be used as food, which naturally contain secretions, either unpleasant in taste or injurious in character. Such are the Sea-kale, Lettuce, and Cichory; which are prevented from becoming *rank*, by heaping earth around their young shoots, or by growing the entire plant in a dark situation. The peculiar secretions, too, are not present in young plants, all whose energy seems expended in the extension of their own structure; hence those kinds, which are afterwards rank poisons, may be eaten with impunity at an early period. Thus the peasants of Languedoc employ young poppies as food; and cattle do not reject noxious weeds in spring, which their instinct would not permit them to touch in summer.

363. As the special secretions of plants are formed in the elaborated sap, they will not be found in those parts, to which it is not afterwards conveyed. They may generally be traced first in the leaves; but in the course of their descent, they are often separated by some particular organ, in which they are concentrated (as it were) to the exclusion of the rest. Thus many of the most powerful medicinal agents are obtained from the bark; some abound most in the roots; other products, especially resins and colouring substances, seem to be chiefly deposited in the wood; fixed oils are generally conveyed to the seeds, where they seem to be deposited for the same purpose as starch,—the nourishment of the embryo; whilst aromatic oils are generally found either in the leaves, in the leafy parts of the flower, or in

the coats of the seed or fruit. Not unfrequently certain little bodies, which have received the name of glands, are seen on the surface of the leaves, from which fluids are poured forth for various purposes. Thus the Nettle is covered with glands of this kind, that secrete an acrid fluid, which, being conveyed through a pointed tubular hair mounted upon the gland, produces an irritation in the wound made by the hair, just as does the poison of the tooth of the serpent or the sting of an insect (§. 97). The little *Drosera* (Sundew) again, exudes a gluey secretion from the surface of its leaves, which serves to attract and retain Insects, the decay of whose bodies seems to contribute to its healthy existence, as it does to that of the Dionæa (§. 246).

364. A detailed account of the various Secretions of plants would not be adapted to this work; and we shall confine ourselves here to a notice of those, which are most serviceable to mankind. Of all these, there are none which can be at all compared in importance with the *azotised* compounds, chiefly formed in certain seeds, which afford a most important article of food to Animals. These compounds are made up of oxygen, hydrogen, carbon, and nitrogen (or azote), united in the same proportions as those which exist in the Fibrin and Albumen of Animals (Anim. Physiol., §. 21). Several of these azotised secretions, having slight differences in properties, but agreeing in all essential characters, exist in Plants; and there are few Vegetables, in which some are not to be found. The most important of them are the *gluten*, which forms a great part of the corn-grains, being especially abundant in Wheat;—and the *legumin*, which exists largely in the Pea and Bean, and in other seeds of the Leguminous tribe. The great abundance of these principles in the corn-grains and in the seeds of the Leguminosæ, renders them peculiarly serviceable as articles of food to Man and Animals; and we accordingly find, that they have been in cultivation from the earliest period of which we have any historical records. Indeed the original form of the *Cerealia* (Corn of various kinds) is now completely lost. In the Potato, also, and other tubers and roots which contain starch in large quantities, there is usually

more or less azotised matter, which adds to their value as articles of nutriment. The use of these substances in the economy of the Plant is not known.

365. Next in importance to these, we are probably to rank Tannin. This is the substance, by the chemical agency of which, upon animal tissues containing *gelatin* (the material commonly known as glue, which forms a large part of the skin of most animals), *leather* is produced. Its chemical effect upon gelatin may be shown, by steeping some oak-bark, or bruised gall-nuts, in water; and then adding some of this fluid to water in which glue has been dissolved. A quantity of flaky matter will fall down, which is, in fact, leather;—its particles being separate from each other, on account of the liquid form in which the elements were brought together. The process of tanning consists in steeping the skins to be converted into leather, in a solution of tannin; this slowly penetrates their substance, converting their gelatin, which would otherwise soon undergo putrefaction, into the compound just mentioned, which is capable of resisting decay. And, as no injury to the texture of the skin is done by this process, it is converted into a substance which, from its pliancy, combined with toughness and durability, is useful for a great variety of purposes.

366. In this country tannin is principally obtained from oak-bark; but as of late years the supply of that material has not been equal to the demand, it has been necessary to look for some other source, from which it may be procured. Several other trees common in this country yield tannin; such are the elm, willow, elder, plum, sycamore, birch, cherry, poplar, hazel, and ash;—but the proportion contained in all, save the two first of these, is not sufficient to render their cultivation for this object a source of profit. Even the common heath has been applied to this purpose; the tannin being extracted from it by boiling. There are, however, many trees of tropical climates, which contain a larger proportion of tannin than that yielded by oak-bark. One of these is a kind of Sensitive-plant (*Acacia Catechu*), which flourishes abundantly in the mountainous parts of Hindostan, and yields the substance known as *Catechu*, or Terra

Japonica (Japanese earth, from its earthy appearance), which is much valued in medicine from its astringent properties, and which acts very powerfully on gelatin. It is a dry extract, prepared by boiling the heart-wood of the tree, cut into chips, and then evaporating the superfluous water. The *Mangrove* tree, of the East and West Indies, is another from which a large quantity of tanning matter may be obtained. This curious tree grows on the borders of the sea and on the banks of rivers; its stem is supported by a large number of branching roots, which rise out of the water in arches several feet high, closely intertwining with each other; and the branches hang down, and send forth similar roots, as in the Banyan (§. 152). The extract made from its bark is used for tanning in many parts of the West Indies and in Hindostan; and it is said to perform its office more perfectly in six weeks, than oak-bark does in ten, producing a leather more firm and durable. In New Holland, there is an abundance of a species of Acacia, which is cut down for the purpose of clearing land; and from this it has been ascertained that an extract may be made, fully equal to oak-bark. As, notwithstanding the distance of the colony, it can be supplied very cheaply, so long as there is a superfluity of the Acacias it will probably take the place in great degree of oak-bark. The Eucalypti of New Holland also contain a large quantity of tannin in their bark.

367. Another secretion of great importance in the arts, and of which new and valuable applications are constantly being discovered, is *Caoutchouc*, commonly known as Indian Rubber. It was first brought as a great curiosity from South America about 150 years ago; and for a long time nothing was known of the source from which it was obtained; nor was it applied to any useful purposes, except the rubbing-out of pencil marks, from which it took its name. It is known to be contained abundantly in the juices of many trees, growing in tropical climates; as well as, in smaller quantity, in many plants of temperate regions: it seems to form an essential part of the *milky* juices (as they are termed, from their white colour, rather than from their properties), which are characteristic of several tribes of Vegetables,

especially of the *Artocarpeæ* (Bread-fruit tribe), *Apocyneæ* (Oleander tribe), and *Euphorbiaceæ* (Spurge tribe) which will be hereafter more particularly described. To the first of these orders, belongs the celebrated Palo de Vacca, or Cow-tree of South America; which yields a copious supply of a rich, bland, and wholesome fluid, closely resembling milk. In the plants of the second order, the milk is usually rendered bitter and poisonous, by the admixture of other secretions: and in the third it is of a very acrid character. In other orders of plants having milky juices, however, caoutchouc forms but a very small proportion of them; such are the *Papaveraceæ* (Poppy tribe) and *Cichoraceæ* (Cichory tribe); and here it is replaced by *opium*,—a substance presently to be adverted to. The juices which contain caoutchouc are obtained, by making incisions into the bark; and the fluid which runs from them soon thickens, on exposure to the air, into a substance of a pure white colour, having neither taste or smell. The dark colour which caoutchouc usually presents, is received from the smoke of the fire over which it is dried.

368. The use of Caoutchouc in the arts and manufactures results from two distinct properties;—its high degree of elasticity; —and its complete impenetrability to water. The modes in which its elasticity is made useful are extremely numerous; amongst others may be mentioned, the employment of it to form elastic webs, which are partly woven with threads spun from it, and which are introduced into braces, saddle-girths, and other bands in which a steady and equable pressure is required. Its impenetrability to fluid has long been known, and was applied by the Indians of South America in the production of waterproof boots; these were made by spreading the juice, when flowing fresh from the tree, over moulds of clay, which could be afterwards broken away from their interior. Similar articles have been made in this country, by keeping the juice in bottles from which the air was excluded; by which means it has been brought over in a perfectly fluid state, without losing its power of hardening when exposed to the atmosphere.

369. But of late years, a much more effectual and ready means has presented itself, of thus employing to great advantage

the valuable properties of Caoutchouc, in the discovery of the power of ether and naphtha* to dissolve it, without changing its properties; so that a kind of varnish may be thus formed, from which, when it is spread over any surface, the dissolving fluid (which is extremely volatile) will evaporate, leaving a very thin coating of caoutchouc behind. It is in this manner, that the waterproof fabrics are made, which are now so much employed for cloaks, wrappers, &c.; and as these are also air-tight, they may be used for air-cushions, mattresses, &c. The fabric consists of two layers of cloth, which are varnished, each on one side, and then passed between a pair of rollers with the varnished sides in contact; so that the two layers are pressed closely together, a thin layer of caoutchouc existing between them. Some idea of the great and increasing consumption of this substance, new and useful applications of which are constantly being discovered,† may be formed from the fact that, whilst in 1830 the quantity imported into England was more than 52,000lbs. (nearly double that imported in the preceding year), the consumption in the year 1833 was nearly 180,000lbs.; and there can be little doubt that it has since increased in nearly, if not quite, as rapid a proportion.

370. The large number of *Oils* obtainable from plants, may be divided into the fixed or fat oils, from which no vapour passes off at the temperature of boiling water; and the volatile or essential oils, which give off vapour at or below that temperature. The latter are the sources of all the odours, diffused so widely through the vegetable kingdom; and furnish, also, some materials of great importance in the arts of life. The fixed oils are all obtained by pressure from the fruits or seeds of plants, especially those of the Nut kind, all of which contain it in

* This fluid is obtained in England from the tar, which passes over with the gas now so universally employed, when coal is heated in closed retorts.

† A patent has lately been obtained for the employment of solid Caoutchouc in saddles and horse-collars. Two objects are here attained by it;—the much increased comfort of the horse, by the equal diffusion of pressure over the surface, by which *galling* is prevented;—and the preservation of the padding beneath, by protecting it from being saturated (as it otherwise frequently is) with the perspiration of the animal.

greater or less proportion. That in the greatest request is *olive* oil; which is obtained both from the pulpy part of the fruit, and from the seeds; that drawn from the former source is regarded as the best, being less liable than the other to become rancid. The olive-tree was originally a native of Syria, Persia, and other hot countries in Asia; but it has gradually extended itself over the South of Europe and the North of Africa. The cultivation of it has been principally attended to in times of peace, of which it was considered as the symbol. It is extremely profitable to the grower, if properly attended to. The young olive-plant bears at two years old; and in six years begins to repay the expense of cultivation, even if the ground beneath it be not made to yield any other crop. It continues to be profitable for a long period, rivalling the oak in longevity, and bearing good crops when the trunk is reduced to a mere shell; so that it is a common proverb where it is cultivated,—"If you want to leave a lasting inheritance to your children's children, plant an olive." Olive oil is very extensively used in the south of Europe, in the preparation of various dishes for the table, for consumption in lamps, for the manufacture of the superior kinds of soap, and for various other purposes. It is used very largely in this country, in spite of a heavy duty; upwards of four millions of gallons having been imported in 1831, of which about half was exported again to other countries.

371. Rape oil is obtained from the seeds of a species of *Brassica*, a plant closely allied to the Cabbage, which is cultivated for that purpose in France and some parts of England. It is much used for burning in lamps; and has the advantage over others, that it remains fluid at a lower temperature. Linseed oil, which is obtained from the seeds of the Flax-plant, is of very general application in the arts; especially in oil-painting, and in the composition of varnishes, for which it is particularly adapted by its property of drying on exposure to the air. This power may be increased by boiling the oil, which is then termed *drying-oil;* it is in this manner that printer's-ink, which is a sort of paint composed of oil and lampblack, is made to dry rapidly. The seed of the Hemp-plant yields an oil nearly as

valuable; and it has lately been found, that a large quantity may be extracted from the cotton-seed; so that each of these three plants is valuable to man in two very different ways. The hard cake, left after these oils have been pressed out from the seed, is used for feeding cattle. Sun-flower and mustard seeds, also, yield a good oil, which is employed in the countries in which these plants abound, as a substitute for other seed oils. A large quantity of oil is now obtained on the Continent of Europe, from the seeds of the Poppy. It was commonly supposed, when this oil was first introduced into use, that it must partake of the narcotic properties of the plant; but this was erroneous; for oil, like starch, may often be separated from the peculiar juices of the plant, without being influenced in the slightest degree by their properties. Poppy oil is a very useful one in the composition of varnishes, on account of its freedom from colour and its drying quality; in the northern parts of France, it is much used by soap-boilers. Oil is also obtained in many parts of the Continent, especially Switzerland, from Walnuts and Hazel-nuts; this is much esteemed by varnishers, for the same properties as Poppy Oil. The influence of climate on the production of oil, is well shown by the fact that, from these nuts, which in England would scarcely yield enough to repay the labour of extracting, half their weight of oil may be drawn in the South of Europe. Nearly the same may be said of the Beech, from the kernels of which about 27 per cent. of oil is obtained in some parts of France and Germany.

372. Another important vegetable oil is that known under the name of Palm Oil; it is obtained from the fruit of two species of Palm, which grow in several parts of Africa, especially in Senegal. One of these is named *Cocos butyracea*, from the buttery nature of its oil, which is much employed by the natives along the Gold Coast as an article of diet, and which, when fresh, is delicate and wholesome. It is imported into Britain in large quantities, chiefly for the soap-maker and perfumer. The quantity retained for home consumption in 1839, was 276,000 hundred-weight. The oil is contained in the kernels of the nuts, which are not very different from those commonly known as

Cocoa-nuts; these last, also, yield a large quantity of oil, which congeals, at the ordinary temperature of the air, into a white fatty substance. In Ceylon, where this fruit is most abundantly produced, its oil is employed by the natives for a great variety of purposes. It makes a most excellent lamp-oil, except from its tendency to congeal by a slight amount of cold; and for this purpose it is employed by the Cingalese; whose greatest consumption of it, however, is for the anointing their bodies. In this country, a process has been discovered, by which the oil may be separated into two parts; one resembling fat, which may be applied to the making of candles; whilst the other is as fluid as most other oils, and is particularly adapted for lamps. The oil is also well adapted to the wants of the soap-maker. Its consumption in Britain is much increasing; in the year 1839 nearly 40,000 hundred-weight of the oil was employed in various ways in this country. The oil known as Ben-oil is of more importance than might be supposed, from the small quantity of it introduced into this country. It is produced from a tree, growing in the East Indies, Egypt, and the Levant, which belongs to the same group with the Tamarind. The peculiarity of this oil consists in its very slight tendency to become rancid, and in its perfect freedom from smell; on which account it is much used by the perfumers, to retain the scent of the more fragrant oils. At a low temperature, it separates into two parts, the one solid and the other liquid; and the latter is employed by watchmakers, in preference to any other oil, for lubricating their delicate works, on account of its having no action upon the metals.

373. The *essential* or *volatile* oils are mostly obtained from the leaves or flowers of plants; sometimes, however, they exist in the wood and bark, or in seeds. In all instances they possess a powerful scent; and the degree of this depends upon the tendency, which the fragrant oil has to diffuse itself. In some of the most odorous flowers, this tendency is so great, that the oil cannot be procured in a separate form; and their perfume is obtained, by causing the flowers to impart it to some fixed oil; for which purpose Ben oil is preferred, where it can be obtained.

The volatile oils are not easily obtained by pressure; but are readily driven off by heat; but this must not be so great for the most diffusible, as that of boiling water. To communicate the fragrance of flowers to a fixed oil, cotton soaked in it is placed in alternate layers with the flowers whose scent is to be obtained, so as to fill a close vessel, which is then placed in hot water for twenty-four hours; during this time, the fixed oil will have imbibed the rich perfume of the flowers, and it is then separated from the cotton by pressure.

374. Those essential oils which are somewhat less volatile, may be obtained by distillation, in the same manner as spirits. The substances which yield them are put into a vessel, with water to prevent their being over-heated. When the water is boiled, the oil passes away with the steam; and, when both are condensed, it floats upon the surface of the water. A large number of oils, possessing great fragrance and strong taste, may thus be obtained from different kinds of plants; and these oils are used in perfumery, in confectionery, and in medicine. The oils of Roses, Lavender, Chamomile, &c. are distilled from the flowers; those of the various plants of the *Mint* kind—Peppermint, Spearmint, Pennyroyal, &c., from the leaves and stems, which contain it in a number of little receptacles near their surface; that of Sassafras from the wood; that of Cinnamon from the bark; that of Caraway, Anise, Fennel, and other Umbelliferous plants, from the coats of their seeds, in which they are stored up in little receptacles; that of Lemons, from similar receptacles in the rind of the fruit; and that of Nutmeg, from the seed itself. Many of these oils contain Camphor, which may be separated from them by exposure to cold. Sometimes the secretion of volatile oil is so abundant, as to make itself perceptible in the atmosphere around, to other senses besides smell. Thus the Fraxinella gives off so much from its leaves, that the air in its neighbourhood is highly inflammable in warm weather. There are some substances, which seem to contain the materials of an essential oil, rather than the oil itself. Thus when water is added to flower of Mustard, an acrid and volatile oil is produced,

very irritating to the eyes; yet no evidence of its existence can be obtained, without the addition of water; so that the latter probably occasions some change of composition, by which the oil is produced. The volatile oil of Bitter Almonds seems to be produced in a similar manner. Perhaps the increased fragrance of our gardens after a shower of rain is due to a similar cause.

375. Into the particular uses of the foregoing oils, this would not be the place to enter; some of them will be noticed in the description of the several orders, to which the plants that yield them belong. There are other volatile oils, of much more importance in the arts and manufactures, which must next be noticed. One of the best-known of these is Oil of turpentine (commonly termed Spirit of turpentine), which exists in combination with resin, forming what is usually known as Turpentine, in all the trees of the Pine and Fir tribe, as well as in some others. The Turpentine is generally contained in special receptacles in the substance of the wood; but sometimes it collects in blisters underneath the bark, which appear during the strong heats of summer. It flows from these as a limpid juice, which thickens on exposure to the atmosphere, when incisions are made into the stem. The common Turpentine is obtained from the Scotch Fir, when growing in the South of Europe, and the Southern part of North America; but it cannot be procured in any large quantity from the same tree when growing in Great Britain. Superior kinds are drawn from the Pistacia of Scio, and from the Larch in Southern Europe. Turpentine is not itself applied to any important use; but the two substances which it contains,—the volatile oil, and the resin,—both serve many purposes. They are separated by distilling the Turpentine with water; which causes the volatile oil to pass over, leaving the resin behind. Oil of Turpentine is extremely useful from its power of dissolving resins, which form the basis of most varnishes; and from its great volatility, it quickly flies off or dries away, leaving a thin coat of the varnishing substance, fixed to the surface on which it has been applied. The most extensive use, however, to which it is put, is that of diluting oil

colours, so that they will flow freely from the painter's brush. No other known fluid would answer this purpose; for it is the only one, which will mix readily with the paint (diluting its thick oil, as water would dilute a syrup or gummy fluid), without in the least degree affecting its essential properties,—and which will also dry rapidly.

376. The very important substances known as *Tar* and *Pitch* are also obtained from trees of the same kind; and they may in fact be regarded as impure turpentines, altered by the heat employed to separate them. A sort of kiln is built up of billets of wood; and round the bottom of this is a channel for drawing off the fluid, which runs down whilst the wood is being burned. Tar may be made from trees which no longer yield turpentine, and also from those which have partially decayed on the ground. Pitch is tar deprived of its more volatile part; this may be separated, either by distilling off the oil, which is an inferior oil of turpentine, or by burning it; in the last process, the volatile oil, being the most readily set on fire, is burned away, and the resinous part remains. In this manner, two barrels of tar will produce one of pitch; and besides the oil, an acid passes off, by the distillation of tar, which much resembles that obtained during the burning of wood from charcoal, and hereafter to be mentioned under the name of the *pyroligneous*.

377. Several other Resins are yielded by plants; some of which, commonly termed *Gums*, are of service in various arts. Such is Copal, which is obtained from a species of Sumach; but though the tree will readily grow in North America and in England, it requires the heat of a tropical climate to perfect its juice; and most of this product comes from Africa. Copal is much valued as a varnish, on account of its hardness and transparency; which qualities cause it to be employed for pictures, fine woodwork, and other similar purposes.—Mastic is another resin, which is used for similar purposes, and is obtained from a tree termed the Lentisk, nearly similar to that which yields the Chian turpentine. Incisions are made in the trunk and branches, during the hottest parts of the summer; and the liquid juice which flows from them, thickens, almost immediately that it is

exposed to the air, into little drops or tears.—Dragon's Blood, so named from its red colour, is a resin which exudes in drops from the stem of several trees growing in the tropical parts of Asia, Africa, and America; it is valued on account of the tinge which it imparts to spirit of wine, and is employed, when thus dissolved, in staining marble and woods.—The substance called Benjamin or Gum Benzoin, is also a resin secreted by a tree that grows in the tropical parts of Asia, especially in Siam and Sumatra. This tree grows very rapidly, so that it yields resinous juice when only six years old, its trunk being then about 7 or 8 inches in diameter. This resin has a very fragrant odour, which probably depends upon its having, mixed with it, a small quantity of essential oil. It is principally used in perfumery, and in the manufacture of pastilles, or incense, which, when burned, diffuse an agreeable odour. Hence the principal consumption of it is in the churches of Roman Catholic and Mohamedan countries; and a much larger proportion of that brought to London is again exported, than is retained in this country.—There are many other kinds of resin, of which small quantities are employed for particular purposes; but the foregoing are those most valuable to mankind.

378. Resinous matter, however, exists in other products, which are termed *Gum-Resins*, from the quantity of Gum they contain; and this enables them to be partly soluble in water, which pure resins are not in the slightest degree. Some of these are valued on account of their fragrancy; and have been employed in the incense burned in places of religious worship, from very ancient times. Thus we find in the earliest records, that the addition of fragrant odours was regarded, as rendering the sacrifices offered to the Deity more acceptable; and the same idea seems to prevail in many Christian as well as heathen countries, at the present time. Frankincense is one of these substances; it is produced from a kind of Juniper growing in Arabia. Olibanum is another of similar character, also produced by a species of Juniper; and Myrrh is nearly allied to these, but the source of it is uncertain.—Gamboge is a gum-resin of very different properties, which is the product of several different

kinds of trees, growing in Ceylon, Siam, and Cochin China. It flows out in a liquid form, when incisions are made in the bark, and is afterwards made solid by the heat of the sun; but it also occasionally exudes from the surface in *tears*. When rubbed with water, it forms a bright yellow fluid, which is much employed in water-colour drawing; the water *dissolves* the gum, whilst the resin remains *suspended* in the form of very minute particles, which may be seen with the microscope. The whole is dissolved in spirit of wine; and this solution is used as a lacquer, to heighten the colour of brass-work, by its golden hue. Gamboge is also a powerful medicine, having a violent purgative effect; and with aloes it is the principal active ingredient, in the nostrum known under the name of Morison's Pills.*

379. The true *Gums* may next be noticed; these are distinguished from the previous substances, by their being entirely soluble in water, whilst spirit of wine does not act upon them. Their solution in water is a thick adhesive fluid, which is used for many purposes in the arts. It serves to unite substances together, in the same manner as glue; and may be used in cases where heat is undesirable. Its chief employment, however, is in calico-printing, being used to stiffen the cloth before the colours are applied, so that they are prevented from running into each other and becoming indistinct. As all trees contain gum in their sap (§. 328), it might be obtained in some degree from any; but it naturally exudes in large amount from some kinds, which, therefore, yield it most readily when incisions are made in the bark. The kind of gum termed Gum Arabic, which is the one most valued, is obtained from a species of Acacia, which flourishes in almost every part of Arabia and Middle Africa; but it is only in the hottest regions, that the gum is produced in much abundance. When the tree first opens its flowers, the gum begins to exude spontaneously from the bark of the trunk and branches; in the same manner as it is often seen to do from the cherry-tree

* It is probably to the bad mixture of the ingredients, by which an undue proportion of this active substance has been contained in a particular batch of pills, that some of the deaths which have occurred from their use, are to be attributed; and in other instances they have resulted from the enormous number of pills taken.

in this country. In the spring, however, when the weather is very dry, the gum can only be obtained by incisions made in the bark.

380. Gum Senegal is similar to Gum Arabic, being obtained from a kind of Acacia differing very little from that which yields the latter; but it is of inferior quality. Gum Tragacanth, which is obtained from a low prickly shrub growing in the Levant, is in some respects different from the foregoing. It does not dissolve freely in water; but forms a thick mucilage with a certain definite proportion of it. If this be mixed with a larger quantity of water, it will separate again after a time and fall to the bottom, leaving very little gum in the water above. This gum is employed in some kinds of calico-printing, in which the chemical action of the dyes on the other gums would injure their qualities. The plant which yields this gum would flourish in England; but it can here only prepare no more of it than is required for its own support; and only possesses a superfluity under the influence of a warmer climate. A large quantity of a gum resembling that of the Acacia, may be obtained from the various species of Lichen growing in this country, by the action of hot water.—The similarity of *starch* to gum has been already noticed, and some of the sources from which it may be obtained have been pointed out; and it is here, therefore, only desirable to add, that the gum obtained from starch is much used in the arts, especially for the purpose of stiffening different fabrics, on which account it is employed largely by calico-printers, under the name of British Gum.

381. The next Vegetable secretion to be noticed is Wax; which, though commonly supposed to be formed by the Bee alone, is undoubtedly present in many plants also. It may be seen in the form of minute scales, upon the outer surface of the Plum and other stone fruits, forming what is known as the *bloom;* and it is by the existence of a thin coating of it, that the leaves of the Cabbage, Tropæolum (Sturtion), and other plants, are enabled to resist moisture. Wax may be obtained by heat, though in small quantity, from the poplar, alder, and several other plants; but it exists in such abundance in the fruit of a

Virginian myrtle, that this has received the name of Candle-berry. In the parts of the country where this tree abounds, it is quite worth-while to collect the berries, for the wax they yield; which, when made into candles, burns with peculiar brightness and freedom from smoke, at the same time giving off a fragrant odour. Another wax-bearing tree exists in South Africa; and the substance yielded by its berries, which is made into candles by the Dutch, is greedily eaten by the Hottentots. In South America there is a kind of palm, the leaves of which have their surface covered with minute scales of wax, which separate when they are dried in the shade; and of this wax, mixed with a small proportion of tallow to avoid brittleness, excellent candles may be made. The leaves are so little permeable to moisture, that they may be used as coverings for houses; and they have been known to sustain the vicissitudes of weather for twenty years in such situations, without requiring to be renewed. The pith and the fruit of this palm also furnish a nutritious food for man and cattle; and the wood is useful in building houses, making fences, &c.; so that it is a very important tree, in the district in which it abounds. Another species of Wax Palm is found in the more elevated parts of South America; growing on the mountain ranges to the prodigious height of a hundred and sixty feet. The wax here exists in the form of a kind of varnish, covering the trunk.

382. A substance nearly resembling *Tallow* is yielded by a tree named the *Croton sebiferum*, which grows abundantly in China, and is described as being the largest, the most useful, and the most widely diffused, of any of the plants of that country. It imitates the oak, in the height of the stem, and the spread of its branches. The seed-vessels are hard brownish husks, not unlike those of chestnuts; and each of them contains three round white kernels, about the size and shape of hazel-nuts, having small stones in their interior, around which the fatty matter lies. From the kernel of the stone, an oil fit for burning in the lamps may be pressed. Almost all the candles burnt in the southern provinces of China, are made from this vegetable tallow, there being very few sheep in that part of the country;

but it does not burn so well as animal fat. A tree abounds on the Malabar coast of India, termed the Piney, which bears a pulpy fruit, that yields a large quantity of very solid tallow, almost approaching wax in firmness, and very superior, for the manufacture of candles, to animal fat. It is not applied to that use by the natives, however, who (on account of the heat of the climate, which prevents the employment of common tallow candles,) are accustomed to burn lamps only, which are fed with vegetable oil. This vegetable tallow might probably be imported in great abundance, and at a low rate, into this country.

383. The last inflammable substance secreted by Plants, which will here be noticed, is *Camphor;* which is much used in the composition of varnishes, besides its employment in medicine. Although chiefly obtained from a species of Laurel growing in the East Indies (where it attains the size of an oak), it exists in numerous plants, especially those yielding aromatic oils. Camphor differs in some degree in its properties, according to the way in which it is obtained. In general, pieces of the roots are put into an iron vessel, within the cover of which (fitted closely down) are cords of rice-straw. When the lower part is heated, the camphor is raised into vapour, and condenses again on the straw above. In old trees, however, the camphor is sometimes found, on splitting the trunk, to exist in a very pure state, in the form of small concretions or tears, in the interior. This camphor undergoes little loss by exposure to the air; whilst that obtained by heat very rapidly evaporates. Besides the uses of this substance already noticed, it should be mentioned that camphor is valuable as a preservative of specimens of Natural History against the depredations of insects; and the most effectual way of applying it, is to have the cases made of the wood of the Camphor tree, which is of a white colour, easy to work, and durable.

384. Opium is the next vegetable secretion which we shall here notice; and this rather on account of its importance in medicine, than because of the large quantity produced; since it is mostly employed in a manner injurious, rather than beneficial, to mankind. Opium is contained, in small amount, in the

milky juices of many plants; but especially in those of the *Papaveraceæ*, or Poppy tribe. The species which yields it most abundantly, is the White Poppy (*Papaver somniferum*); but this does not produce it in any large amount in temperate climates, and is cultivated in Europe chiefly for the oil yielded by its seeds (§. 371). The juice is obtained by making incisions in the capsules or seed-vessels (commonly termed *heads*), whilst they are quite green; and that which hardens upon them is scraped off. Many kinds of opium are known to the importers of drugs; but their difference only results from the varieties of climate in which they are grown, and from the mode in which the juice is obtained and prepared. Some kinds are very much adulterated. More opium is now raised in Hindostan, than in any other country; and the principal demand for it has been in China. Opium is a substance of very compound nature. A large proportion of it consists of a gum soluble in water; there is also, however, a small quantity of resin and of caoutchouc. The ingredients which act so powerfully on the animal body, however, constitute but a very small proportion of the whole. The most important of these, are two substances of an alkaline character (being capable of uniting with acids to form a salt), which are named Morphia and Narcotine. The properties of the first of these are directly sedative; that is, it causes sleep or the relief of pain, without any previous excitement. The first effect of Narcotine, on the other hand, is to stimulate. These alkalies exist in the opium, in combination with a peculiar vegetable acid, termed the *meconic;* and they are separated by chemical processes, since, in order that the medicinal effects of either may be most advantageously produced, it is desirable to administer them separately.

385. The chief consumption of Opium, however, is unfortunately not for the purpose of curing disease, or of relieving pain, but for the production of a species of intoxication; the constant indulgence in which has a great tendency to degrade the mind, and to enfeeble the body. The quantity necessary to produce the desired effect increases with habit; so that the confirmed opium-eater often takes as his single dose, repeated many times

through the day, a quantity sufficient to poison any one unaccustomed to its use. The practice of taking opium often commences with the occasional use of it, for the purpose of allaying pain or procuring sleep; and those who are obliged to have occasional recourse to it for this purpose, should be on their guard against taking it more frequently than is absolutely necessary. For such persons, Morphia is the most desirable medicine; since it produces more completely the effects they desire, without that excitement to the nervous system, which leads to the employment of it as a source of pleasure. The quantity of this drug annually consumed in England, may be stated at about 35,000 lbs.; whilst that which has been introduced into China, in spite of the laws which prohibit it, has for some years averaged more than 3½ *millions* of pounds, the value of which considerably exceeded that of the tea exported. The quantity seized by the Chinese government, in March 1839, was upwards of three million pounds.

386. We shall next notice some of the principal Colouring matters secreted by plants. On these are dependent the varied hues so beautifully and abundantly distributed through the vegetable kingdom; of which some at once delight the eye of man, whilst gazing upon the garden, the meadow, or the forest; whilst others, extracted from the interior, even of plants of the dullest aspect, contribute to his comfort and luxury in various ways. The colouring secretion most universally diffused through plants, is that termed *chromule*, on which the colour of all green parts depends. It is found in little grains, which adhere to the inside of the cells beneath the cuticle; and the formation of it is due, as formerly stated (§. 288), to the influence of light, in fixing carbon from the atmosphere. The brightness of this green colour soon disappears after the death of the part; and it is not unfrequently seen to alter its hue, whilst vital actions are going on in it. Thus the leaves of many trees, as the Lombardy Poplar, change to yellow in autumn, long before their fall; whilst others, as the Berberry, Sumach, &c., turn to red. This alteration is due to an increased absorption of oxygen, which is no longer given out by day; and the chromule may be artificially converted,

by the action of acids, first into a yellow and then into a red. The red colour of many flowers possesses the same properties as that of leaves when thus altered; and this fact will possess a higher degree of interest, when it is shown, as it hereafter will be (Chap. XII.), that the leafy parts of flowers have the same general structure as leaves, and often differ very little from them. It is further probable that all the colours of flowers are caused by the presence of chromule, altered by various chemical means; in all instances it may be seen, that these colours exist in the same parts,—namely, minute globules contained within the cells. It has been observed that the colours of many flowers may be greatly changed by cultivation; in some species, as the Dahlia and Poppy, great varieties occur without any obvious cause,—the seeds of the same parent, raised in the same soil, producing flowers of extremely different hues; whilst in other cases, the hue is manifestly influenced to a great degree by the nature of the soil.

387. The colouring matter of rapidly-growing parts has seldom sufficient permanence, when removed from the plant, to render it valuable for the purpose of staining cloth, &c.; and the substances used for this purpose, in the arts of the dyer, calico-printer, &c., are chiefly obtained from the heart-wood, roots, or bark; sometimes, however, from the softer parts, as the leaves and fruit. The principal dyes, by the combination of which all varieties of shade may be produced, are blue, violet, red, yellow, fawn, and black; and substances, yielding all these, are produced in abundance by different tribes of plants.

388. Of all the *blue* dyes, *Indigo* is the most important. This is obtained from the juices of several different species of plants, of which some grow in almost all parts of the torrid zone. These plants are raised from seed, and are of very rapid growth,—being ready for cutting at the end of two months. A subsequent growth from the same roots, is again ready for the sickle, in six or eight weeks; and more may be subsequently obtained. In India, it is not considered advantageous to obtain more than four crops from the same seed, as the produce of each is less than that of the preceding; but in Egypt, the seed is sown only once

in seven years, and two crops are obtained in each year. The indigo, which seems to be nothing else than the *chromule* of the plant, is usually extracted by fermentation. The plants are laid in a vat, and covered with water; and in about 18 hours they begin to swell, and to give off a large quantity of gas,—the water at the same time acquiring a green tinge. This process is allowed to go on, until the colouring-matter of the vegetable tissue has been entirely yielded to the water; but if it continue too long, so that any putrefaction take place, the dye is destroyed The fluid is then drawn off into another vat, where it is violently agitated, for the purpose of separating the pulp from the water. The former consists of little grains, which, during the process, turn from green to blue by attracting oxygen from the air; and, by further processes, it is dried into a solid mass, constituting the indigo of commerce. Nearly all the indigo imported into Britain, is produced in the East Indies; its amount averages about *seven millions* of pounds every year, of which, however, more than half is exported again, chiefly to the North of Europe and Italy. Owing to the great variation in the productiveness of the crops, the price of Indigo is almost constantly changing. In the season 1824-5, it was nearly 11*s*. 6*d*. a pound; whilst in the season 1829-30, owing to an over-abundant supply, it was only 4*s*. 4*d*. At the former rate, the value of the average quantity annually imported would be about *four millions sterling;* and at the latter, scarcely above *one and a half.*

389. This valuable dye has so strong an attraction for almost every kind of fibrous texture, whether animal (as woollen or silk) or vegetable (as linen or cotton), that it will impart to it a permanent colour, without the assistance of a mordant*. In order to apply it, however, it must be *dissolved* in water; and this can only be accomplished by a change in its chemical nature, which restores it to its original yellow-green colour; the stuffs, after being dyed, change again to blue, by exposure to the

* Mordants are substances used in dyeing and calico-printing, to hold together the particles of the texture dyed, and those of the dyeing material, when these have not a sufficient attraction for each other. If not so united, many colours would be washed off, as readily as they are laid on.

air. This process appears to injure in some degree the durability of the colour; and it is preferable to apply the dye, when first separated from the plant. The brilliant blue cloths of Africa and China, which are superior in hue to those of any other part of the globe, are produced in this manner.

390. The juices of several plants, growing in the different countries of the East, are used by the natives of those countries, in the same manner as Indigo; and might probably furnish a good substitute for it, if prepared with sufficient care. The use of Indigo as a dye, on a large scale, is comparatively recent. It was not until long after the discovery of America, that it was commonly employed in England; and the use of it was forbidden by the governments of some European countries, from the fear that it would supersede the use of *Woad*, which was then very extensively cultivated. This dye was known to the Ancient Britons, who stained their bodies with it; and it was the principal blue dye; until the introduction of Indigo. Its colour is much less lively than that of Indigo, but it is more durable; hence it is commonly employed in union with that and other dyes, but seldom now by itself. Woad (*Isatis sativa*) is cultivated in many parts of Europe; and is grown in considerable amount in Lancashire. Its stem is about three or four feet high, and about half an inch in diameter; it divides into many branches, which are loaded with leaves. It is cut down with a scythe, when the flowers are about to appear; and afterwards at intervals of about six weeks;—three or four crops being usually obtained in one year. The plants are first washed, and then dried in the sun, without which they will begin to putrify, their green colour turning black. They are then conveyed to a mill, where they are ground into a paste. This paste is afterwards subjected to several processes, for the purpose of drying it. It is finally used nearly in the same manner as indigo; with which, indeed, its colouring matter, if extracted in the same manner, is found to be nearly identical.

391. A *Violet* hue is easily given to cloth, by mixing blue and red dyes in any required proportion; but there are some plants, which yield a violet or purple dye, without any admix-

ture. The chief of these is *Logwood*, the produce of a tree growing in the bays of Campeachy and Honduras,—the native country of the Mahogany. When Logwood was first introduced into this country as a dye, the use of it was forbidden by Government, on account of its "deceitful" character; the colour it communicated being fair to the eye, but speedily departing. The art of fixing it by mordants, however, being afterwards discovered, this substance came into general use; and it is now imported largely from Jamaica, as well as from its original country. The part which yields this dye is the heart-wood; this is hard and heavy, in consequence of the amount of secreted matter contained in it; and it yields its colour readily to water, when this is boiled upon its chips. The deep violet or purple hue of the fluid, first changes to a yellowish tint, and finally becomes black; but this change may be prevented by the use of proper mordants. The chief use of this substance, however, is in dyeing black, and in producing all shades of grey. The quantity imported into Britain in 1839 was 23,000 tons, the value of which was above 180,000*l.*

392. The principal *Red* dye obtained from the vegetable kingdom, is *Madder*, the produce of the *Rubia tinctoria*, a plant which grows naturally in the Levant, and which is cultivated with success in the South of Europe; its cultivation does not answer in England. The colouring-matter is obtained from the roots, and is not sufficiently formed until the third year; the roots are taken up in the autumn, after the leaves have fallen off. They are then carefully cleaned, dried, and reduced to powder. A great variety of colours, varying from lilac to black, and from pink to deep red, may be produced by the application of different mordants to the stuff, before it is placed in the madder. These are partly due to the intermixture in this substance of two distinct colouring principles, a fawn and a red. The latter, if separated from the other, is much more brilliant; and various processes have been devised for the purpose. The best of these requires that undried roots should be employed; and they are largely imported into this country with this object. The quantity of madder employed in Britain in 1838, was upwards of five

thousand tons; and of the roots, more than four thousand. The value of these would be together about 600,000*l*.

393. Another valuable Red dye, is obtained from the wood of the *Cæsalpinia crista*,* commonly known as *Brazil* wood. Though abundant in that part of South America, the tree is a native of other parts of the world; and it was known under its present common name, before the discovery of that country. And, in fact, the portion of that continent which bears the name of Brazil, was so named in consequence of the numbers of these trees, which were found growing there. As in the case of Logwood, it is only the *duramen* (§. 131) of this tree, which is of any service; the remainder being colourless. The colour obtained from this wood is brilliant; but it is not so permanent as that of many other substances. It is generally used to heighten the effect of other dyes. Red ink is commonly made, by boiling this wood in beer, wine, or vinegar, to which alum has been added. Of late years the consumption of this wood in Britain has much diminished; whilst that of another kind, termed Peach-wood, or Nicaragua-wood (so named from the Gulf of Nicaragua, whence it was first imported into England), has greatly increased, so as to be now nearly double the first. The colour obtained from it is brighter, and more delicate, than that yielded by Brazil-wood.

394. Another red dye, now largely employed in England, is obtained from a Lichen, commonly termed *Orchilla*, which abounds in the Canary and Cape de Verd Islands, and which is sometimes found (though of inferior quality) on the rocks of Guernsey and the Isle of Portland. The plant is usually imported without any preparation; it is afterwards dried and reduced to powder, and then submitted to some chemical processes, which produce from it the beautiful liquid dye, known as *Archil*. It is seldom used by itself, as its colour is not permanent; but it is chiefly employed to give a brightness to the

* An allied species of this tree, the *C. pluviosa*, also a native of Brazil, is remarkable for a constant flow of water from the points of its leaves, which falls down in drops, like a shower of rain.

hues of stuffs, dyed with other substances. Another species of Lichen yields the dye termed *Cudbear*. Several other red dyes might be enumerated, which are used in small quantities for particular purposes. Among the most important of these is *Alkanet*, which is obtained from the roots of the *Anchusa tinctoria*, a native of the Levant and the warmer parts of Europe, but grown also in England. This colouring principle is not soluble in water; but it gives a deep red colour to oils, wax, and unctuous substances. It is consequently used chiefly to colour oils, ointments, lip-salves, &c.; and it is sometimes applied to the staining of wood, when dissolved in oil. Notwithstanding the apparent insignificance of these purposes, above 50,000 lbs. of it are annually imported into this country for home use, besides what is raised in Britain.

395. Many good *Yellow* dyes may be obtained from plants; and the most important of all those used in Britain, is procured from a plant of native growth,—*Weld*, or *Wold*, or (as it is sometimes called) Dyer's-weed. This grows spontaneously in many parts of the country, on uncultivated wastes; and it is a very hardy plant, preserving its verdure through frost and drought. It is nearly allied to the Mignionette; but is a much taller plant, attaining the height of three feet before blooming. It takes two years to come to maturity, and is gathered whilst the seed is ripening. The plants are dried, and then transferred to the dyer, who at once extracts the colour by boiling; there is reason to believe, however, that the seeds contain the really important part; and that, if they be saved, the trouble which arises from the bulk of the whole plant, may be avoided. The colour is also separated, in the form of a yellow powder, for the use of the paper-stainers, who employ much of it. A much larger quantity of weld is used in England, than is supplied by cultivation; and it is consequently imported from abroad. This is much to be regretted; as there is good reason to believe, that it will thrive and yield a handsome profit, on lands so poor as not to be profitably cultivated in any other way.

396. Another very excellent yellow dye is obtained from the bark of the *Quercus tinctoria*, or Quercitron, a species of

Oak common in America, the timber of which is employed largely in building. This bark is employed in the United States for tanning; and its colour being considered a defect, this is removed by a chemical process. More than a thousand tons of it, however, are annually imported into Britain: and it is here much valued, on account of the number of different shades of colour, which it may be made to produce, as well as on account of its superior durability. A much greater demand exists, however, for the dye termed *Fustic;* which is extracted from the wood of a species of Mulberry tree, that grows spontaneously in Brazil and the West Indies. It does not yield above one-fourth the amount of colouring matter obtained from Quercitron, and its colour is not so lively; but it is more efficient in combination with some other dyes, and is used with indigo to dye Saxon green, and with salts of iron for drab.

397. *Arnatto* is another dye of a reddish yellow, employed for particular purposes; it is obtained from the crimson pulp lying between the husk and the seeds of the Arnatto tree, which is a native of both the East and West Indies. It is brought to this country in cakes, which are made by boiling down the pulp; and these are of a brownish red, giving a bright orange, when dissolved in water with the addition of an alkali. Its hue is not permanent, however; and it is seldom employed by itself, except for giving colour to cheese; for which it is valued, on account of the ready communication of its colour, without imparting any unpleasant flavour or unwholesome quality. One of the most beautiful yellow colouring substances, is that known as *Saffron;* but it is too expensive to be much employed by dyers. Its chief use is in medicinal and culinary preparations, to which it imparts its brilliant hue and agreeable flavour. Saffron is the produce of a kind of Crocus, which is cultivated in England, as well as in France and Spain. This plant flowers in October; and the flowers are gathered, even before they are full-blown. The *stigmata*, or points of the pistils (§. 434), of these flowers, are then picked off; and the rest of the flower is thrown by as useless. These little bodies, constituting the Saffron, are next very carefully dried, and pressed between paper. Its high price re-

sults from the very small amount of it produced, even on good land ; even when the roots are planted thickly, the average quantity for the whole three years (beyond which they should not be allowed to remain in the ground,) is not above 26 lbs. per acre. *Turmeric* is sometimes used as a substitute for Saffron, the colour it produces being very bright, though deficient in durability. This dye is procured from the roots of an East Indian plant named *Curcuma longa*, which has also been cultivated in the West Indian Islands with success. These roots are not unlike ginger, either in figure or size ; and the dye brought to this country consists simply of the roots, either whole or reduced to powder. It is sometimes used to give brilliancy to other hues ; and is employed as an ingredient in yellow varnishes.—Several other plants affording yellow dyes might be enumerated ; but the foregoing are the chief. It may be mentioned, however, that the clothiers of some parts of Lancashire and Yorkshire, make use of common *Heath* for their yellow and orange dyes ; this, with a proper mordant, is said to produce on woollen cloth a more beautiful colour, than either weld or quercitron ; but it is not so permanent.

398. Almost all Vegetables contain more or less colouring matter, capable of affording *fawn* colours, or brownish hues inclining to yellow, red, or green. The dye chiefly employed for this purpose, however, is obtained from the Sumach, a native of the south of Europe and of Syria. The shoots of this plant are cut down every year, close to the root ; and after being dried, they are reduced to powder by means of a mill. An infusion of this powder yields a greenish fawn colour, which may be altered by mordants. The principal use of Sumach, however, is in dyeing black, in the manner presently to be described. The colouring matter of the husks of walnuts forms an excellent dye for wool ; and it is much esteemed among the French dyers, for the agreeable and durable hues it affords without the assistance of mordants. In order to obtain this colouring matter, the husks are kept in water for a year or two ; after which they give out much more of it than when fresh. The *Henna*-juice, which is employed by the ladies of the East for the purpose of staining their

nails, is a very permanent brown dye; the colour not disappearing, until the substance of the nails is changed by growth. It is also employed for dyeing ordinary stuffs; but it has not been introduced into this country.

399. The Vegetable kingdom affords several substances, which are capable of themselves producing a permanent black dye; but a much larger amount of such materials is required, than could thus be obtained; and the black colour of our cloths and stuffs is procured by a chemical process, of which one important ingredient is furnished by Plants. This process consists in adding *gallic acid* to a solution of iron; by which an insoluble bluish black substance, the gallate of iron, is immediately formed. If a cloth, therefore, previously steeped in a solution of iron, be immersed in an infusion of any vegetable matter containing gallic acid, a black dye will be communicated to it. Almost all vegetable substances having an astringent taste, contain gallic acid; but especially the Oak tribe. It is from the abundance of this acid in the Gall-nut (which is an excrescence resulting from a kind of inflammation, excited by a wound of the soft tissue of the leaves or young shoots by the gall-fly), that it takes its name. Gall-nuts are not, however, formed upon the Oak of this country;* but upon a smaller species, which grows wild in the countries bordering on the Mediterranean. They are usually pounded and then boiled in water, in which the cloth is steeped; and this is afterwards placed in the solution of iron (commonly termed copperas). The colour thus communicated is not a deep black, but rather a dark blue. It is improved by logwood, which is boiled with the copperas; and the stuff should have been previously dyed of a deep blue, with indigo. A similar process is employed in the manufacture of common black writing-ink, which essentially consists of gallate of iron suspended in water by means of a small quantity of gum; and logwood is here also added to improve the colour. Galls are imported from the East Indies, as well as from Turkey; but of late years they have been in less

* The Oak Apples, however, are similar formations; as are also various other excrescences, formed upon different parts of the Oak, which is infested by several species of Gall-fly

demand, in consequence of the introduction of another source, from which gallic acid may be obtained at a much cheaper rate. This is in the cups of the acorns of the Velani Oak, a species which grows abundantly in Greece, and in the maritime parts of Asia Minor. These cups, which do not contain gallic acid in the same proportion as gall-nuts, are known in commerce by the name of Valonia; but in consequence of their cheapness (being only about one-fifth the price of galls) the consumption of them is very great. During the year 1830, the quantity of gall-nuts employed in England was 2,297 cwt.; whilst that of Valonia was 86,538 cwt. Many other astringent substances may be used as black dyes with iron; and a good deal of the Sumach imported into Britain is used for this purpose, as are also walnut husks in France; the shells of chestnuts, too, have been employed, although not profitably. In India, the juice of the fruit of the Myrobalans, which is not unlike a plum, is used for dyeing black with iron; and when the pulpy portion is freed from the stone, which is useless, it contains more gallic acid than an equal weight of galls, and might be made a profitable article of commerce.

400. From gallic acid, we may naturally proceed to speak of the other acids, which are produced by Vegetables. These are all, like the foregoing substances, formed by the plant itself, from the elementary bodies it receives as food; and thus they may be regarded as true products of vegetable secretion, and not as merely separated by the plant from the surrounding soil. In this last light we must regard the earths and alkalies obtained from plants, and not as products of their secreting processes. The acid which is employed in largest quantity, is the *Tartaric*. This is obtained from the crust that is deposited by wine, when kept a long time; the amount of which depends, chiefly, upon the degree of acidity in the wine. The crust which goes by the name of Argol, chiefly consists of tartaric acid in combination with potash, forming what is commonly known as *Cream of Tartar;* and this requires to be purified from its colouring-matter and other impurities, before it can be employed in the arts. The acid is easily obtained in a separate form by chemical processes; and it is employed for many purposes, which cannot be

answered by the cream of tartar. Its chief use is in many processes of dyeing and calico-printing.

401. Another vegetable acid much used in the arts is the *Oxalic*, which is well known as a violent poison. From the resemblance of its crystals, in size and general form, to those of Epsom salts, it has not unfrequently been administered by mistake, with the most dreadful consequences. This acid is found united with potash, in the leaves of the Wood-sorrel and common Sorrel; and the oxalate of potash is prepared from their leaves in large quantities, in Switzerland and the neighbouring countries, where these plants grow abundantly. Its long needle-like crystals may be seen lying amongst their tissues, if a thin section of the stem or leaf-stalks be placed under the microscope. This salt is known as Salt of Sorrel; but it is sometimes sold under the name of Salt of Lemons, to which title it has no right whatever. The acid may be separated from it, as in the former instance; and it is employed for many purposes by the dyer and calico-printer; as well as for removing the stains of ink, iron-moulds, &c., which it does without injuring the texture of the stuff.

402. The acid which gives sharpness to the juices of lemons, oranges, limes, and a variety of other fruits, and is known under the name of Citric acid, is likewise one which has many important uses, besides that of imparting a peculiarly refreshing character to these juices. It is largely employed by calico-printers, who now usually import their own lemon-juice, and concentrate it for themselves. At one time, the citric acid, which is not combined in the juice with any earth or alkali, was obtained by chemical processes in separate crystals; but it is now found, that the impurities of the juice do not interfere with its use in calico-printing; and it is employed for this purpose, almost in its original state. For other purposes, however, pure citric acid is required; and this is partly made in Sicily, where Lemons are abundantly produced, and from which island, with the neighbouring continent of Italy, the greater part of the juice consumed in Britain is imported. Pure citric acid is used in the preparation of the best morocco Leather; for improving a beau-

tiful scarlet dye, produced by a preparation of tin; and for altering the hue of some colours, which are exclusively used in the dyeing of silk. Besides its use in the arts, Lemon-juice is very largely used in the navy, for the purpose of preventing the complaint termed Scurvy; which is very apt to be brought on by the continued use of salt meat by confinement, but particularly by the want of fresh vegetables. During long voyages, a regular allowance is made to each man, which he is required to use as a medicine. This, however, has been now rendered less necessary than formerly, since the art of preserving meats and vegetables in a fresh state has been brought into general use. Citric acid exists in many of our commonest fruits,—such as the cranberry, cherry, red whortleberry, and the hip of the wild-briar; whilst in the red gooseberry, the currant, the bilberry, the black cherry, the wood strawberry, and the raspberry, it is mixed with an equal proportion of *malic* acid, which exists alone in apples, pears, and other fruits. It is interesting to notice the uses of the acids in these situations. It has been formerly stated, that gum or starch, when acted on by a vegetable acid with a moderate degree of heat, is converted into sugar; and this is exactly what takes place in fruits during ripening,—which process consists in the conversion of the starch of the hard unripe fruit into sugar, without any diminution in the amount of acid, which is sometimes indeed really increased. whilst its taste is concealed by the sugar.

403. One more vegetable acid may be mentioned; though it probably does not exist as such, in the substance from which it is obtained, but is formed by the heat employed to set it free. This is *pyroligneous* acid, formerly called acid spirit of wood, which is procured by subjecting wood in closed iron retorts to a strong red-heat; the vapour that is given off, partly consists of this acid, mixed with tarry matter, which is separated by a second distillation. This acid, which in some degree resembles very strong vinegar, is used by the dyer and calico-printer; and it is also employed for making pickles and other culinary preparations, in which an acid of great strength is required. The impure acid has been found to possess, in a remarkable degree,

the power of checking the putrefaction of animal substances, even when applied in very small quantity; this is due, however, not to the acid, but to a certain ingredient in the tarry matter, which is mixed up with it, and which, when separated under the name of *creosote*, is now well known as a valuable medicine, especially for the relief of tooth-ache. The discovery of the influence of this substance in controlling putrefaction, would be of great value, if it were not, that, by no subsequent process of cooking, can the tarry flavour communicated by it to the meat, be got rid of.

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404. Having thus passed in review some of the most important products, afforded by the secreting processes of Plants, for Man's use and benefit, and having been obliged to confess our almost entire ignorance of the processes they serve in the Vegetable economy, we might proceed to the next division of our subject; but it would be wrong not to pause here for a moment, to contemplate the important inferences which may be drawn from the foregoing details, in regard to the Power, Wisdom, and Goodness of the Almighty Designer. His Power is scarcely anywhere more remarkably displayed, than in the immense variety of products, which are elaborated out of the three simple elements—oxygen, hydrogen, and carbon,—by processes, which, as far as we can understand them, appear to be of the most simple description. His Wisdom is strikingly evinced in the diffusion of these products over the whole globe; so that there is scarcely a country, which does not naturally contain those, which may be most useful to its inhabitants. And his Goodness is peculiarly manifested in the adaptation of these products—the formation of which (we can scarcely doubt, although we cannot understand) must have an object as regards the plants themselves—to the use of Man, in ministering to those various wants, which have sprung out of his condition as a rational being, endowed with higher faculties and more varied powers of enjoyment, than those of the beasts which perish, and yet dependent for the most favourable use of these, upon the judicious

employment of the means, with which a bountiful Providence has abundantly supplied him. The nourishment of Man's body in health, his restoration in disease, the clothing that covers him, the varied hues which he can communicate to this, the colours which delight his eye in the verdant landscape, or in the skilfully painted picture, the odours which refresh his senses, the timber of which his habitations, his manufactories, his ships, are partly or wholly constructed,—these are but a few of the provisions, which the benevolence of the Creator has made for his comfort, in the organisation of the Vegetable World. Who, then, shall say, that it is less fertile in the evidences of a Designing Providence, than the Animal Creation?

CHAPTER XI.

OF THE PRODUCTION OF LIGHT, HEAT, AND ELECTRICITY BY PLANTS.—MOTIONS OF PLANTS.

405. It has been already stated that, by the operation of these agents upon the Vegetable system, are chiefly maintained those changes which make up the *life* of each being. (§. 9.) If Light be withdrawn, several of the most important of these are speedily checked. If Heat be suspended, all of them directly cease. With regard to the influence of Electricity, less is known, and nothing can be positively stated. But Light, Heat, and Electricity are not only required by Plants as conditions of their growth; but are sometimes *produced* by them.

406. There are few instances in which *Light* is evolved from living Plants; but these few are very curious. Many flowers, especially those of an orange colour, such as the Sun-flower, Marigold, Nasturtium, &c. have been said to disengage light in serene and warm summer evenings, sometimes in the form of sparks, sometimes with a steadier but more feeble glow. Light is also emitted by certain species of Fungi, especially those which grow in moist and warm places, where light is entirely excluded, as in the depths of mines. The light is perceived in all parts of the plant; but chiefly in the young white shoots. It ceases if the plant be deprived of oxygen, either by being placed in a vessel from which the air has been exhausted, or in some other gas; and it re-appears, when the plant is restored to air. No luminousness is perceived after the death of the plant. It would seem probable, therefore, that this extrication of light is in part connected with that conversion of oxygen into carbonic acid, which, as already mentioned, takes place very rapidly in flowers,

and in the whole substance of the Fungi (§. 290.), and which may be regarded as a sort of slow combustion. An evolution of light has also been observed to take place, from dead and decaying wood of various kinds, particularly that of roots; and also from Fungi whilst decomposing. This corresponds with the luminousness of certain Animal bodies after death.

407. It is well known that the higher Animals alone possess the power, of keeping the temperature of their bodies up to a certain fixed standard; and that in the lower tribes, the heat of the body varies with that of the atmosphere, being frequently but a very little above it; so that these, giving to the touch a sensation of cold, are termed cold-blooded animals. Still, they have *some* power of generating or producing heat, which is shown by their power of resisting the influence of extreme cold for a long time. In regard to Plants, much doubt has been entertained at different times, whether they could be said to have a *proper heat* or not; or whether their temperature is not entirely dependent upon that of the atmosphere. But this doubt has resulted from a very limited view of the processes of the Vegetable Economy, against which it is desirable to guard the young reader.

408. The production of heat in Animals is principally dependent upon the conversion of Oxygen into Carbonic acid, by its union with the carbon thrown off in respiration; and just as the rapid combustion of charcoal in oxygen gives out a great degree of heat, so does the slower process of union in which the respiration of human beings really consists, disengage heat more gently. (ANIM. PHYSIOL. CHAP. VI.) Now in Plants this process of respiration takes place so slowly (in comparison with Animals), and from a surface so openly exposed to the atmosphere, that it could scarcely be expected that there should be any sensible elevation of the temperature of the part from this source; especially when it is considered that a constant loss of heat is taking place by evaporation.*

* See TREATISE ON HEAT. This fact is readily understood, by pouring a little water, a little spirit of wine, and a little ether, one after another, upon the back of the hand. Although they may have been all of the same temperature, the

409. Some recent experiments, however, made with an apparatus that would indicate extremely slight changes of temperature, have proved that the process of Respiration in Plants *is* accompanied by a disengagement of heat; but in order to establish this, it was necessary to compare the temperature of a living plant with that of a dead one, having the same proportion of moisture at its surface; since in this way only, could the true effect of respiration in producing heat be known, whilst the evaporation was continually preventing the manifestation of it, by cooling the surface. In this manner it was found, that the heat of the surfaces of plants is raised by their respiration, from 1 to 2½ degrees above what it would otherwise be.

410. It has long been observed, that the interior of large trunks possesses a temperature more uniform than that of the surrounding air; being cooler than the atmosphere in summer, and warmer in the winter. There are at least two causes of this occurrence.—Wood is a slow conductor of heat; thus, if a piece of stick and a rod of iron of equal sizes have one end heated in the fire, the farther end of the stick will be nearly cold, whilst that of the iron is too hot to be handled. Further, the conducting power of wood is still less *across* the grain (or through the stem), than *with* the grain (or along the stem); so that changes in the external air will not readily affect the centre of a large trunk; and, accordingly, it is found that, the larger the trunk on which the observation is made, the greater is the difference between its state and that of the air.—The other reason is, that some motion of the sap takes place even in winter; and the fluid taken up by the roots principally comes from a depth in the ground, at which, from the bad-conducting power of the soil, the temperature is nearly uniform throughout the year.

411. The evolution of heat by Plants is most evident, at those periods of their existence, in which an extraordinary quantity of carbonic acid is formed and given off. This is the case during the germination or shooting-forth of seeds; and though the heat

hand is cooled least by the water, more by the spirit, and most by the ether,—in proportion, in fact, to the rapidity with which these fluids respectively pass off in vapour.

produced by a single seed is too soon carried off by surrounding bodies, to be perceptible, it accumulates to a high degree, when a number are brought together, as in the process of *malting* (§. 283,4), in which the thermometer has been seen to rise to 110°. The same may be said of that other period of vegetation, in which an extraordinary amount of carbonic acid is evolved,—that of flowering (§. 285). It is evident that, from the little *substance* of the parts thus heated, and the large amount of *surface* they expose to the air, the heat will be carried off by the atmosphere, almost as rapidly as it is produced. Still in some flowers, a considerable amount of heat can be proved by the thermometer to be disengaged; thus, a Geranium has been found to possess a heat of 87°, when the air around was at 81°.

412. As in the case of seeds, however, the production of heat is most sensible, when a number of flowers are crowded together; and this is still more the case, when they are inclosed in any general covering, as are those of the Arum family. In these the flowers are small, and are very closely set upon a stalk, which is called a *spadix;* and the whole cluster is surrounded by a large leafy sheath called a *spathe*. It is in these flowers, that the size of the fleshy disk is the most considerable, and the quantity of carbon to be united with oxygen is therefore the greatest; and the combination of this cause with the other occasions the temperature of the clusters to be raised very high. A thermometer placed in the centre of five spadixes has been seen to rise to 111°, and one in the centre of twelve to 121°,—while the temperature of the external air was only 66°. The increase of temperature commences with the opening of the flower; and it is greatest at the time of the shedding of the pollen (§. 433).

413. That the development of heat in these cases is owing to the conversion of carbon into carbonic acid, is proved by two kinds of experiments. In one, the cluster of flowers was placed in pure oxygen, by which this change was performed much more rapidly than in common air; and the heat given out was much greater, than that evolved by a flower-stem at the same stage, in common air. On the other hand, a spadix being put into

nitrogen (the gas which forms the greatest part of common air, seeming to have for its object to dilute the oxygen, which by itself would be too powerful for the support of animal and vegetable life), the formation of carbonic acid was altogether checked, and no heat was given off; although the opening of the flower, and the shedding of the pollen, took place to all appearance as usual.

414. So little has been satisfactorily ascertained, regarding the connection of *Electricity* with the processes of Vegetable growth, that it seems undesirable here to dwell upon the manifestations of this agent which sometimes occur. It may be stated, however, that, whilst on the one hand, the condition of the atmosphere in regard to Electricity has evidently a striking influence on the rapidity of their growth (some plants having been known to increase in the most extraordinary manner during thundery weather), the electricity developed by the changes which take place in the economy of plants, has probably a very powerful influence on the condition of the atmosphere. It is well known that by all chemical changes, such as occur in every process of vegetation,—from the absorption of the crude sap, to its final conversion into the substances which are to remain fixed or permanent through a long series of years,—electricity is produced. Further, the mere evaporation of water from the surface of the leaves will do the same; and thus a constant series of changes in the electric state of plants will occur, which will communicate themselves to the atmosphere.

415. The general electric state of plants is found to be that termed *negative*;* and if any circumstances cause the atmosphere to be *positively* electrified through a considerable space, some great commotion of the elements is not unlikely to take place. Hence, the dreadful hurricanes, which occasionally devastate the West Indian islands, may be in some degree accounted for. The evaporation of the water from the surface of the surrounding ocean, tends to make the air above it positively electrical; and this, too, at the very time when the brilliant light and genial

* See TREATISE ON ELECTRICITY.

warmth of the sun, are causing the vegetation of the land to possess an opposite condition. "How wonderful," it has been remarked, "are the operations of nature! The silent and peaceful growth of a vegetation, whose splendour fascinates the eye, develops an agency, which, opposed to that produced by the rapid but unobserved evaporation from the surface of the surrounding ocean, tends to load the atmosphere with conflicting elements, from the depth of whose strife issues thunder proclaiming the approach of the hurricane and tornado."

Of the Motions of Plants.

416. The gradual movements of the parts of plants, which occur as a part of the natural changes involved in their growth,—such as the extension of their roots beneath the ground, and the elevation of their leaves and flowers by the upward growth of their stems and branches,—have been already noticed; and the causes which influence them have been assigned, as far as our knowledge of them extends (§. 107, 309). A curious experiment has been recently performed, which proves in a remarkable manner the influence of light, on the direction of the growth of these parts. Some seeds of Cabbages, Mustard, and Kidney-beans, were placed in Moss; and were so arranged, that the only light they could receive was from a mirror, which threw the solar rays upon them from below, upwards; the natural direction of their growth was in this manner completely changed, —the stem being sent downwards, and the roots upwards.

417. We have here to notice, however, another set of movements displayed by Plants; in which an evident change of place occurs, whilst they are being observed for a short time. One of these is known as the *sleep* of plants, from the circumstance of its generally occurring in the evening. This consists sometimes in the folding-together of the leaves, in other cases in their drooping, and occasionally in their clasping the stem; it is most displayed in Leguminous plants having pinnate leaves (§. 238.); and in them the lateral leaflets commonly fold together, whilst the leaf-stalks are bent downwards on the stem. Many flowers, also, exhibit a regular movement of the same description;—

closing together at night, and unfolding in the morning. There are a few species, however, which unfold at night and close during the day. There are some, too, which close during the day, when the sky is overcast and a storm is threatened. These changes seem almost entirely dependent upon the degree of light, to which the plant is exposed; for they may be made to take place at the contrary periods, by keeping the plants in a darkened room during the day, and placing them at night in strong lamplight. It is usually some little time, however, before they become accustomed to the change; and their movements are at first irregular. The mode in which light produces these movements has not yet been ascertained; but it can scarcely be doubted, that it is by its influence on the exhalation of fluid from the soft tissues, on one side of the bending part more than on the other. Supposing that the part were otherwise bent, the influence of light upon the cells of the convex side would cause them to contract, and thus straighten it,—a change which we shall presently see to be elsewhere effected by another cause acting in like manner. Whilst, if the part were straight in the dark, so that the leaves were erect, and the flowers expanded, the influence of light, acting more on one side than on the other, would cause it to bend towards that side, by causing the tissue to contract.

418. The influence of water, or of varying degrees of moisture in the atmosphere, seems often to produce movements in the living plant, as well as in dead portions of its tissues. It is in this way that the closure and unclosure of the Rose of Jericho, and the Lycopodium of Peru, are occasioned,—the one by drought, the other by the contact of fluid. This is easily accounted for, by supposing that the cells on one side are larger, and have thinner walls than those on the other; and these will, therefore, be most easily distended when placed in water, and will soonest lose their fluid in drying. The beards of the Geranium and Wild Oat curl up in dry weather and straighten in damp; those of some other plants perform the contrary movement. Such parts of plants are often used in the construction of *hygrometers*, to indicate the amount of dryness in the atmosphere, to detect dampness in beds, &c

419. Some of the most interesting among the vegetable movements are those concerned in the deposition of the seed. The Balsam termed *Impatiens noli-me-tangere* has a seed-vessel or capsule, formed of five divisions or valves; which, when the seed is ripe, suddenly separate from one another and curl inwards, scattering the seed to some distance. Now an examination of the tissue of these valves shows, that their outer part consists of much larger cells than the inner, and that the fluid contained in it is the densest. By the laws of *Endosmose* (§. 118), therefore, the fluids contained in the tissue of the interior will have a tendency to pass towards the outside, and will distend its vesicles still more. This distension of the outside layer will manifestly give the valves a tendency to curl inwards; just as when two thin plates of metal, which expand unequally by heat, are soldered together, and, heat being applied, the compound plate bends towards the side which expands least. This tendency continues to increase up to the time when the seed is ripe; and it is then so powerful as to cause the separation of the valves from each other, and to occasion the rolling inwards of each. Now it has been found that, if the valves be placed in a fluid more dense than that which the valves contain, such as syrup or gum-water, the fluid will be drawn off from their cells, according to the same law of Endosmose; and the cells on the exterior will be emptied soonest, on account of their being larger and fuller than the others; so that the valves become straight, and even curl outwards. But if they be put into water, the Endosmose, still taking place towards the side on which the fluid is densest,—namely the interior of the cells,—will distend them still more, and will cause the valves to curl inwards more powerfully than at first. Another instance of movement with the same object, which may be explained in a similar manner, is that of the seed-vessel of the common Squirting-Cucumber (*Momordica Elaterium*). This, when ripe, very readily separates from its stalk; and its pulpy contents are violently forced out from the aperture thus left. The pulpy matter surrounding the seeds occupies the centre of the fruit, and, by its own increase in amount, distends the cavity; the

elasticity of the walls, therefore, occasions their violent contraction, when an aperture is formed in any way, by which the distension is relieved.

420. Such explanations, however, will by no means account for all the evident movements of Plants; and it is necessary to suppose their living tissues to be endowed with a property termed *contractility*, by which they are enabled to contract upon the application of a stimulus, just as do the muscular fibres of animals. The Vegetable kingdom affords many examples of this kind of contraction. Thus, if the leaves of the common Wild Lettuce be touched, when the plant is in flower, the part will be covered with milky juice, which is forced out through the stomata, by the contraction of the cells or vessels beneath. Again, in the flower of the Berberry, if the base of the stamen be touched with the point of a pin, the filament or stalk will bend over, so as to strike its top against the style or central pillar of the flower. This movement will hereafter be seen (§. 437) to be connected with the process of *fertilisation;* and it must be frequently caused by the contact of insects, which thus assist in that function. There is a curious New Holland plant, named Stylidium, sometimes cultivated in green-houses in this country, which has a tall column rising from the centre of its flower, and consisting of the stamens and style united; this usually hangs down over one side of the flower; but if it be touched ever so lightly, it starts up with a jerk, and rapidly swings over to the opposite side.

421. One of the most interesting of all the Vegetable movements, however, is that displayed by the *Sensitive plant* (Mimosa pudica). This is a Leguminous plant of the Acacia kind, which has its leaves very much subdivided into leaflets. When spread out in sunshine, they present no peculiarity of appearance; but at night they fold together as in sleep, more completely perhaps than the leaves of any other plants. If, when expanded, one of the leaflets be slightly touched, it will close towards its fellow; the neighbouring leaflets will presently do the same; the vein upon which these are set will bend downwards, and meet the one on the opposite side of the midrib; the midrib itself will afterwards

bend down upon the stem; and, if the plant be in a very irritable condition (from its functions being in a state of great activity), the other leaves are sometimes affected in a similar manner. The explanation of this very curious phenomenon requires, that the structure of the parts concerned in it should be explained. It is evident that the cause of the movement must be in some way propagated from the part touched, to the parts where the change actually takes place,—namely the points where the leaflets join the veins, the veins come from the midrib, and the midrib from the stem. At every one of these points, there is a little swelling or *intumescence*, formed of very spongy cellular tissue, and containing a great deal of fluid in its cells. If the *under* side of the intumescence at the foot of the leaf-stalk be touched, its vesicles, being very irritable, contract and force out the fluid they contain; and this necessarily pulls down or depresses the leaf-stalk and all that it carries. If, on the other hand, anything distend the cells on the upper side of the intumescence, the leaf-stalk is pushed down, as it were, in a similar manner. The intumescence at the origin of each vein, and at the base of each leaflet, seems to possess the same properties, in a degree proportional to its size; and they are all connected together, by the vessels and woody tubes of the midrib and veins. Now, when the tissue of any of the leaflets be touched, it appears to contract in the same manner as does that of the Wild Lettuce; but instead of squeezing out its fluid upon the surface, it forces it through the vessels into the upper side of the intumescenees at the base of itself and its fellow; and these leaflets are thus caused to fold down and meet each other. The fluid forced out from the under side of their intumescences is probably carried to the upper side of those at a little distance; and thus the neighbouring leaflets also are depressed. The depression of the veins upon the midrib, and of the midrib or footstalk itself upon the stem, will follow in like manner; the extent to which the movement is propagated, being dependent on the amount of fluid expelled from the lower side of the intumescence, in the parts where it has already taken place.

422. Various other stimulants, besides the touch of a hard

body, will produce similar effects. Thus, if electric sparks be communicated to the lower side of the intumescence, or the rays of the sun be concentrated on it with a burning-glass, a similar contraction of its vesicles, and depression of the leaf, will follow. In this, as in the foregoing instance, the leaves return after a time to their usual condition. Several species of the Acacia tribe, growing in warm climates, exhibit corresponding changes in a less degree.—The closure of the fly-trap of the Dionæa (§. 246.) may be probably explained on similar principles; the part here irritated, is the tissue at the base of the three thorns, on each side of the leaf; one of which must be touched, in order to excite the movement.

CHAPTER XII.

OF THE REPRODUCTION OF PLANTS.

423. THE limits which have been set by the Creator, to the duration of the life of each being, that exists at any one time on the surface of the globe, would cause the earth to be speedily unpeopled, were not a compensation provided in the faculty of Reproduction,—or the formation of a new being similar to itself,—possessed by every kind of Plant and Animal. This power of creating (as it were) a living structure, with all its wondrous mechanism,—possessed, too, in Animals of the faculties of sensation and thought, and in Man the residence of an immortal spirit,—seems at first sight more extraordinary and mysterious, than any which we elsewhere witness. Yet it is not perhaps so in reality. The processes which are constantly taking place during the life of each being, and which are necessary to the maintenance of its own existence, are no less wonderful, and no less removed from anything which we witness in the world of dead matter. When the tree unfolds its leaves with the returning warmth of spring, there is as much to interest and astonish, in the beautiful structure and important uses of these parts, as there is in the expansion of its more gay and variegated blossoms; and when it puts forth new buds, which by their extension prolong its branches over a part of the ground previously unshaded by its foliage, the process is in itself as wonderful, as the formation of the seed that is to propagate its race in some distant spot. Thus it is that scientific knowledge heightens our interest in Nature, by showing that, in those things which seem most common, there are as many sources of interest and instruction, as in that which, from its apparently mysterious character, is usually regarded with more curiosity.

424. In the lowest plants, the process of reproduction is as simple as that of their growth. Each single cell of the *Red Snow* (§. 48, Fig. 14) for example, produces within itself a number of little particles; which, at a certain period, are set free by the bursting of the parent-cell which incloses them. These granules then gradually enlarge,—deriving their nourishment from the air and moisture around; and in time they acquire the size of the parent plant, and in their turn produce a new family within themselves, which at the proper time they set free. A similar process takes place in the *Yeast-Plant* (§. 56, Fig. 18). In the *Confervæ* (§. 41, Fig. 11),—in which a number of cells are united together, end to end, in each filament,—the several cells in like manner set free from their interior the little green particles, which serve to propagate their kind; but the parent cells do not lose their own lives, in thus sending a new generation into the world; for, instead of bursting, they allow the granules to pass out by a small aperture which forms in their walls. The growth of these particles within the parent cell may be distinctly traced: at first they are seen adhering to its inner wall; then they separate themselves from it, and float in the fluid it contains; then they are seen to move, while yet within the cell; and after they have passed out, they continue their motion, even in an increased degree, for some time. At last they attach themselves to some fixed object, and their development into new plants then begins. The particle gradually enlarges, and forms a cell containing fluid; this cell takes an oval form, and a partition then appears across it, dividing it into two; one of these is elongated in the same manner, and is again subdivided; so that at last, a complete filament, consisting of many cells, is produced;—this, in its turn, sends out reproductive particles from its cells, which go through the same processes. The curious movement of these granules (which any one possessing an ordinary microscope may observe for himself, by watching the reproductive processes in the common Confervæ of our streams,) has given rise to the notion, that they were to be regarded as *animalcules*, at this stage of their existence;—a notion which is only mentioned here, to point out its absurdity; since, whatever may be the cause of

these movements (which is still obscure), they do not afford any evidence of being guided by Sensation and Will, of which no real Animal can be entirely destitute.

425. In all these cases, the process of Reproduction is performed in a manner as simple as that, which any of the functions of Vegetable Life present to us. There is nothing more wonderful in the fact, that a cell should produce the rudiments or germs of new cells, in its interior, than that it should develope additional cells which are to form parts of its own structure, (as in the Yeast-plant, §. 56, and higher plants in general,) from its outside. Each may be regarded as a Law of Nature;—which is only saying, that it is the mode in which the Creator operates. Now we shall find that, in higher plants, the essential part of the reproductive process is really the same—following the same general laws; and it is one of the most interesting results of scientific research, to see that things which *appear* widely different, may often prove to be closely connected. We may hence learn a lesson, too, which is very useful in the ordinary concerns of life,—not to judge too hastily by *appearances*. Nothing could *seem* more unlike, than the production of the seed of some noble tree, from the elegant flower, with all its complex apparatus of parts,—and the propagation of the humble kinds of vegetation we have been considering, by the simple contrivances just described. And yet it will be seen that, although in the former there is much of an *additional* character, subservient to particular purposes, yet the mode in which the germ is at first produced, is *essentially* the same.

426. The first stage of this increasing complexity, is seen in the higher Sea-weeds; in which, of the large number of cells that the whole plant contains, only a small part are appropriated to this function. Sometimes these reproductive cells are spread over the whole surface of their leaf-like expansion; but sometimes they are restricted to the extremities of the plant. In the common Bladder-wrack (*Fucus vesiculosus*, Fig. 13), which abounds on most of the shores of Britain, a swelling may be seen at the end of each of its divisions, which is distinguished from the rest by its yellow colour, when the fructification which it

contains is mature. In this swelling, a number of pores or minute apertures may be distinguished; and if the substance be cut across, it will be found that, beneath each of these pores, there lies a cell larger than the rest, and partly separated from it. This cell, when the fructification is ripe, passes out through the pore, and soon after bursts, setting free the minute particles it contains; and these, like the granules of the Red Snow or of the Confervæ, develope themselves into new cells; by the multiplication of which, a new plant similar to the parent is gradually reproduced. Now this cell, thrown off from the rest of the structure, and containing reproductive particles, which it afterwards sets free, corresponds with what in the higher Cryptogamia are called *spores*. These spores take the place of *seeds*, in this division of the Vegetable kingdom. We shall hereafter (§. 431, 440, &c.) trace the differences in their structure.

427. The processes of Reproduction in the *Lichens* and *Fungi*, appear to be as simple as those just described. Cells are seen in certain parts of the structure, which differ from those composing its own tissue, and which are destined to be cast forth from it, when the reproductive particles it contains are mature. The immense number of these reproductive cells or spores, which are contained in the different plants of the Fungus tribe, has been already noticed (§. 50); and the various organs which contain them, will be hereafter described. One of the highest forms of this group, is the common Mushroom; in which there is a very distinct separation of the fructifying, from the nutritive system. The spores are contained in a number of little tubes, which are arranged side by side in the membrane forming the *cap* of the Mushroom, and in the thin plates (commonly known as the *gills*), which spread from the centre on the under side of this; whilst between this part and the roots, is a distinct stem. The whole energy of the Fungi seems directed towards the propagation of their race; and the duration of life in individuals is usually very transient. In Lichens, on the other hand, each individual frequently exists for many years, and its powers of propagation are much inferior. Indeed some Lichens do not form any distinct spores; but multiply themselves by little bud-like

bodies, which they form in hollows of their surface. In the common Cup-Moss, for example, (which is really a Lichen), these little bodies may be seen in the form of a fine greenish powder, in the hollows of the cups; and from these, when they are removed from the parent plant, new individuals will spring.

428. In the *Liverworts* we find a similar provision, as already noticed (§. 32); but here there is a distinct set of organs of fructification raised above the general level of the plant, as shown in Fig. 5. The little bodies, forming as it were the spokes of the wheel, are cases containing spores or reproductive cells; and these are scattered, when mature, by a set of elastic spiral filaments which lie among them. When it begins to develope itself, the spore does not altogether burst and emit the granules it contains, as in the Algæ; but its outer coat only ruptures, and a long tube projects from its interior, within which new cells are seen to grow, taking their origin from the granules or minute germs, which the spore contained. These cells gradually increase into a leafy expansion, from the lower part of which root-fibres proceed; and this in time acquires the appearance of the original plant, and forms its own organs of fructification.

429. The organs of fructification in the *Mosses* (§. 27) are extremely beautiful and delicately formed; the provision for the development and dispersion of *spores*, which in themselves resemble those of the Marchantia, being more complex than in the Liverworts. The little *urns*, mounted upon long stalks, which are peculiar to this group (§. 27), are furnished with lids, that drop off when the spores within them are mature; these spores having been developed around a central pillar termed the columella. Around the mouth of the urn is a very beautiful fringe, termed the *peristome;* the various forms of which aid the Botanist in distinguishing the genera and species of Mosses. This fringe is much influenced by moisture; and its movements probably aid in the dispersion of the spores. The subsequent changes which take place in the spore nearly correspond with those described in the last section; the principal difference being, that a number of tubes are put forth instead of a single one. Each of these tubes can be perceived to contain some of the little

granules, which the cell produces within it; and every one of these is capable of itself forming a perfect plant; as has been ascertained, by cutting the tubes into several pieces. In general, however, all these go to form one young Moss,—the cells which they produce uniting together at an early period; and thus the process is rendered much shorter, than if the whole plant had to be developed from a single cell.

430. In the *Ferns*, again, we meet with another form of the same process. The spore-cases are here developed on the backs, or at the edges of the leaves, and differ in form from those of the Mosses; but the spores which they contain, could not be distinguished from theirs. The *thecæ* or spore-cases are usually nearly globular bodies, attached to the leaf by short stalks, as seen at *b*, Fig. 79. Although they are singly almost too minute to be distinguished by the unassisted eye, a number of them clustered together form the spots or ridges on the under side of the leaves, which are termed *sori;* these are shown at *a*. Each theca is surrounded by an elastic ring, which has a tendency to straighten itself; and when the spores are mature, the theca splits across, and the two halves are separated by the straightening of this ring (as seen at *c*), so as to allow the spores to escape. If a Fern-leaf, whose fructification has come to maturity (as may be known by the brownish tinge of the yellow or orange spots or ridges on its leaves), be placed with its underside upon a piece of white paper, this will be found in a day or two covered with a very fine brown dust. These are the spores which are scattered by the bursting of their cases. The process of development of these spores presents several points of interest. In its first stages it closely resembles that of the Marchantia. The outer coat of the spore ruptures, and the inner one projects into a long tube; within which, as well as within the original cavity, new cells are formed from the germs included within it. The first tendency of these newly-formed cells is to grow together,

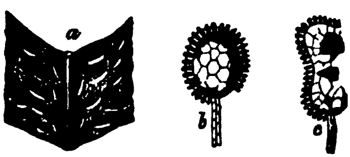

FIG. 79.

and to increase into a leaf-like expansion, very much resembling that of the Marchantia. In the middle of this (which has received the name of primary frond), a knot or protuberance gradually makes its appearance; and this is afterwards prolonged above into a sort of stem, and below into a root. From this stem, the true leaves or fronds are afterwards developed, unrolling themselves after the manner formerly described (§. 25); and, when these make their appearance, the primary frond decays away, leaving no traces of its existence. In this very curious process, we see that the Fern passes, as it were, through the stage which is permanent in the Marchantia; but that when it attains a higher form, the organ, which was only for a time subservient to its existence, decays away.

431. Many instances of a similar kind present themselves in the Animal kingdom. Thus the Frog comes forth from the egg in a state resembling that of a Fish,—breathing by gills instead of by lungs, possessing a long tail by which it moves itself in the water, and destitute of legs. Subsequently legs are produced, which render its tail unnecessary; and lungs are developed, which perform its respiration more effectually than gills; and the first two sets of organs, though they permanently exist in Fishes, disappear in the Frogs, as soon as they have served their temporary purpose. Corresponding changes, hardly less striking than this, take place during the development of every one of the higher Animals; and in every instance we see that, when a higher form is attained, the parts which had their uses in an inferior condition of existence, are cast off as cumbrous and unnecessary. How beautifully does this principle apply to the history of the development of the Human soul! At first it is entirely dependent for its activity, on the impressions which it receives through the bodily frame, with which it is connected. The calls of hunger, the presence of unaccustomed objects, strong impressions upon its senses, first excite its attention; and all its subsequent acquisition of knowledge, depends upon similar influences. Perfect in their kind as are the organs of sensation, by which these impressions are communicated, there are still bounds to their operation. All that their highest exercise, with the aids derived from the most refined ingenuity, can effect in this life,

serves but to give to the philosophic mind a glimpse of the wonders of Creation; and there can scarcely be to such a mind a more powerful *natural** argument in favour of a future state, than that which rests upon the vast amount of knowledge, of which the sources are presented to Man, and the insatiable desire for it which he possesses, compared with his very limited power of satisfying that desire, within the short duration of an ordinary life. All analogy, then, leads to the conclusion, that with the mortal body, the soul shall cast away those instruments, which are adapted only to the present material finite state of existence, and shall be endowed with more direct means of becoming acquainted with those glorious truths, which here it only sees "as through a glass, darkly."

432. To return from this digression.—In reviewing the processes of Reproduction in Cryptogamia, we perceive that they are everywhere essentially the same. The spore, or reproductive cell, contains a number of granules, each of which is capable of producing a new cell, at the expense of the fluid which its parent contains; and these new cells are able, either together or separately, to develope themselves into plants similar to their parents, without any other influences, than those which they receive from the light, air, and moisture, which surround them. In the lowest cryptogamia, we have seen that these granules are thrown at once, as it were, upon their own resources; being set free by the parent-cell before their development into new cells has commenced. But in the higher, we have observed that they remain within the parent cell, which seems to elaborate or prepare their nourishment. Now we shall find that the real essential difference between the Phanerogamic and the Cryptogamic (the flowering and the flowerless) plant, consists in this,—that the former possesses a series of organs fitted to receive and cherish the germ, and to assist in its early development, of which the latter is destitute; and that the presence or absence of those parts, which are ordinarily known as constituting the flower, is of no primary importance. These parts are often absent, without the process of Reproduction being thereby affected; and, on

* By this is meant an argument drawn from the Natural World, as distinct from the Revealed Word of God.

the other hand, there are many flowers, which appear perfect to the uninstructed eye, but which are totally destitute of fertility.

433. The parts of a flower essentially concerned in the reproductive process are the *stamens* and *pistil*. The stamens are little bodies, having yellow heads mounted on long stalks, which are seen *around* but not *in* the centre of the flower. These stalks are called *filaments;* whilst the heads are called the *anthers*. Each head is usually seen to be more or less completely divided into two parts, which are termed anther-lobes. These are commonly united together; as in Fig. 80, *a*, *b*, *c*, *d;* but sometimes they are separated, as at *e;* and occasionally only a single lobe is present, as at *f*. Within the anthers are produced a number of minute yellow bodies, usually of a globular form, which together constitute the fine dust, known as the *pollen* or *farina* of the flower. Each grain of pollen, when examined with the microscope, is seen to consist of a cell, exactly analogous to that which constitutes a spore. It has two or more coats, which enclose a fluid; and in this, a large number of extremely minute granules may be seen with a good microscope. These granules are probably the germs of new cells; being analogous to those which are sent forth from the Red Snow, the Confervæ, and the Yeast Fungi. They may be seen to move within the parent cell, or pollen-grain, previously to the time when its walls become too thick to allow of their being observed through them; and, when the contents of the pollen-grain are mixed with water, they are seen to be constantly performing a sort of vibratory motion. The anthers, or receptacles of pollen, which evidently correspond with the capsules or spore-cases of the Cryptogamia, burst when their contents are mature, and scatter the grains forth. They have various ways of opening; sometimes they split along their length as at *a*, Fig. 80; sometimes transversely, as at *b*; sometimes by little openings at their

FIG. 80.—DIFFERENT FORMS OF STAMENS: *a*, lily; *b*, lemna; *c*, potato; *d*, berberry; *e*, ginger; *f*, sage.

extremity, termed *pores*, as at *c*; and sometimes by *valves*, as at *d*. These different methods are characteristic of different tribes of Flowering plants.

434. Now the portion of the reproductive system in the Phanerogamia, to which nothing analogous exists in the lower tribes, is that which is denominated the *ovarium* or seed-vessel; this occupies the centre of the flower, being sometimes situated above, and sometimes apparently below, the point at which the leafy parts of the flower arise from the axis which bears them. This ovarium is the part, in which are formed the *ovules* or young seeds; and these, after being fertilised in the manner presently to be described, ripen into the perfect seeds. Sometimes it consists of several evident divisions; in other instances, these are united together, more or less closely; and all mark of a division may even disappear. The adjoining figure represents the centre of a flower, in which the several parts of the ovarium remain separated; three only are seen, the others being concealed by them. These separate parts are termed *carpels*. Each carpel is surmounted by a sort of pillar, termed the *style*; which usually expands at its summit, into a fleshy surface called the *stigma*. When the carpels adhere closely together, their styles also frequently unite, so as to form a single pillar; which sometimes, however, divides again into several branches at the top. The ovarium, with its style and stigma, is then called the *pistil*; and sometimes each separate carpel, with its own style and stigma, receives the same appellation. An excellent illustration of an ovarium consisting of many carpels, appearing externally single, but each really separate from the rest, is the Orange; the juicy part of which fruit is the ovarium, composed of a number of carpels adhering together, but not so closely united as to prevent their being torn

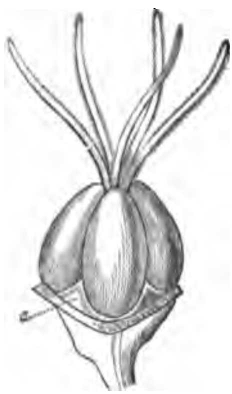

FIG. 81.—PISTIL OF CORIARIA MYRTIFOLIA, showing distinct carpels and styles.

apart. The position of the pips or seeds of the Orangè, will give a good idea of the manner in which they are usually situated within the carpels, especially when they are few in number. Sometimes, however, they are attached to the whole length of the carpel, from one end to the other, as is seen in the common Pea, of which each pod is a separate carpel. The portion of the carpel from which the ovules arise, is usually thick and fleshy, and is termed the *placenta.* The section of the pistil of the *Whortleberry,* (Fig. 82) will give an idea of the arrangement of the parts in an ovarium, whose carpels and styles have united. The ovarium *a,* of this flower is wrapped over by the leafy portion of the flower itself; which is seen to rise beyond it at *b.* The centre of the ovarium is occupied by a thick fleshy placenta, formed by the union of that of the several carpels; and on this the ovules are clustered. Above is seen the signal style with its stigma. Another variety of the same kind of structure, is shown in Fig. 83; here the ovarium, *b,* is in like manner

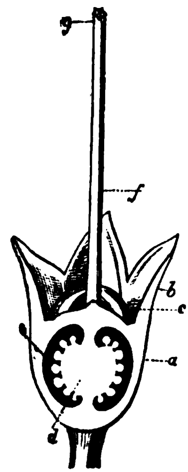

FIG. 82.—PISTIL OF VACCINIUM AMŒNUM; *a,* ovarium; *b,* calyx; *d,* placenta; *e,* ovules; *f,* pistil; and *g,* stigma.

enveloped by the outer part of the flower, *a;* and the partitions between the carpels have entirely disappeared, so that the only one central pillar is left, around which the ovules are clustered. There is another common form of the ovarium, of which that of the Pansy or Heartsease, Fig. 84, may be taken as an example: in this, the partitions have disappeared; but the placentæ of the several carpels, instead of remaining clustered

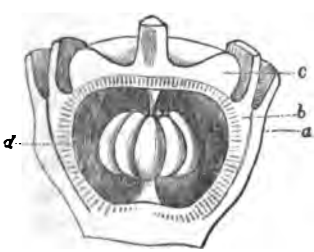

FIG. 83.—OVARIUM OF THAMNEA UNIFLORA; *a,* calyx; *b,* ovarium; *c,* disk; *d,* ovules.

together, are attached separately to the walls of the ovarium as at *a*.

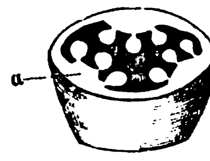

FIG. 84.—OVARIUM OF VIOLA TRICOLOR; *a*, placenta.

435. These two sets of organs are by no means constantly united, however, in the same flower. The *staminiferous* or stamen-bearing flowers, are frequently distinct from those which are *pistilliferous* or bear pistils. When they occur on some other part of the same plant, it is said to be *monœcious* (single-housed); if on a different plant, it is *diœcious* (or double-housed). Sometimes the same collection of flowers contains some perfect ones, with others staminiferous, and others pistilliferous only. There is reason to believe that, when either set of organs is not developed, the rudiments of it really exist; for these parts are frequently made to appear by cultivation.

436. If the ovarium be cut into, previously to the opening of the flower, it will usually be found to contain a great number of the ovules or young seeds. These are at that period quite soft; and their interior is filled up with a kind of pulp, which is enclosed in two or more envelopes. These seed-coats do not entirely cover the central envelope, but leave a small opening, which is called the *foramen*. This opening may be easily detected in the perfect seed (although it has there nearly closed up), by soaking it in water, and then pressing out the fluid that has been absorbed, which will be seen to issue from this little orifice. The foramen, as will presently appear, has a very important purpose in the fertilization of the seed; which, at the period now described, contains no trace of the germ of the new plant.

437. This germ appears to be conveyed into it from the pollen, in the following curious manner. The little grains or cells, when set free from the anthers, fall upon the stigma of the pistil. In general the anthers are situated above the stigma,—the stamens being longer than the pistil in flowers that are erect or upright, and shorter in those which hang down; but sometimes a special provision is necessary, for the conveyance of the pollen to the stigma, especially in monœcious or diœcious plants.

This function is often accomplished by Insects; which, in going from flower to flower in search of honey, cover over their bodies with pollen-dust, and rub them accidentally against the pistils of other flowers. When the pollen falls on the stigma, it is caused to adhere to it by a honey-like secretion from its surface; and after a short time, it undergoes a remarkable change, which closely resembles that already described in the spore of the Cryptogamia.

438. The outer coat of the pollen-cell appears to burst at one or two points, and to allow the inner coat to pass out through it in the form of a tube. This tube insinuates itself between the cells of the stigma, and passes down between the long and loosely-arranged cells of the style. It gradually extends, until

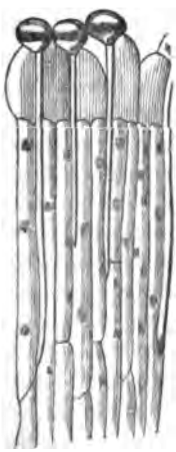

FIG. 85.—SECTION OF THE TOP OF THE STYLE OF SNAP-DRAGON; showing the passage of the pollen-tubes between its cells.

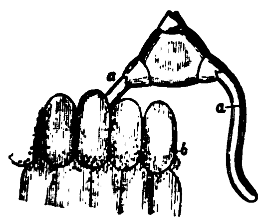

FIG. 86.—POLLEN-GRAIN, OF ŒNOTHERA BIENNIS, sending its tubes a, a, between the cells, b, of the stigma.

it reaches the ovarium itself, even when the style is several inches long. The pollen-grains are not always globular, but are sometimes triangular, and emit a pollen-tube at each corner, as in Fig. 86; such are analogous to the spores of Mosses, which put forth several tubes. The tubes, when they arrive at the ovarium, direct themselves towards its different chambers, and have been seen to enter the apertures in the several ovules; which are at that time directed towards the part of the base of the style, from

which the pollen-tubes project themselves. Sometimes a consi derable change in the position of the ovule is necessary, in order that the foramen should be applied to the right portion of the wall of the ovary; but this change always takes place, just as the pollen-tubes are passing down the style. The granules which the pollen-grain originally contained, are seen to pass down the tube; and some of them are conveyed by it, into each ovule. Whilst yet within the tube, they are seen to develope themselves into new cells; and these cells form the rudiment of the future plant.

439. The germs are thus conveyed into a sort of receptacle, where they are supplied with nourishment, that has been previously prepared and stored up for their use by the parent structure; and they are thus greatly assisted in their early development. The pulpy matter contained in the ovules, consists of starch and sugar; and these nutritious substances are absorbed by the cells of the embryo, which increase at their expense. The first increase of these cells does not so much tend, however, to form those parts which are afterwards to be developed into the stem, root, and leaves; as to produce those temporary structures, termed *cotyledons* or seed-leaves (§. 21), which are destined, like the primary frond of the Ferns, to assist for a time in the development of the permanent structure, and then to wither and decay. Hence, at the time of the ripening of the seed, the cotyledon (which is sometimes double, sometimes single —see §. 440—2) forms the greatest part of the embryo or young plant. Besides this, the seed contains a considerable quantity of starch, destined for the nourishment of the young plant, when it is beginning to sprout, and whilst yet unable to take in food for itself. This starch is sometimes absorbed into the tissue of the cotyledons, rendering them thick and fleshy, as in the Pea or Bean; and then these, with the small germ to which they belong, form the entire contents of the seed. In other instances, however, the cotyledons are thin leafy organs, and occupy, with the germ, but a small part of the seed; the remainder then consists of a separate store, which closely resembles the yolk-bag of the egg, and is termed the *albumen*. This is the case in the seeds

of all Monocotyledonous plants; and also in some Dicotyledons, as the Ash and Horse-chesnut.

440. The structure of the seed of the two principal divisions of the Phanerogamia, is shown in the adjoining figures. In Fig. 87, is seen that of the Bean, a *Dicotyledon*, after the seed-coats have been stripped off, and the cotyledons separated. The two large fleshy lobes, *a*, *a*, are the cotyledons, into which the whole of the starch, originally contained in the ovule, has been absorbed. Between these is the real germ; the upper extremity of which, termed the *plumula*, subsequently developes itself into the stem, and puts forth leaves; whilst the lower part, which is always directed towards the foramen, becomes the root. The plumula sometimes presents the appearance of the plant in miniature; its leaves and buds being quite discernible, though on a very small scale. The subsequent development of the germ contained in the seed into the perfect plant, is that which in its early stage is known as *germination*. Of the causes which excite it, we shall presently speak. When a seed like that of the Bean begins to germinate, it first swells and bursts its seed-coats; the plumula then extends upwards, bringing the cotyledons just above the surface of the ground; whilst the radicle penetrates it in the opposite direction. In some plants, however, the cotyledons remain underground, as in the Oak; and there are a few, in which they are entirely absent. The cotyledons, when exposed to the light, become green, and perform for a time (though imperfectly) the functions of leaves; at the same

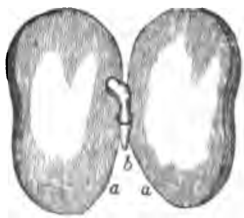

FIG. 87.—SEED OF THE BEAN, with its cotyledons; *a*, *a*, separated; *b*, germ.

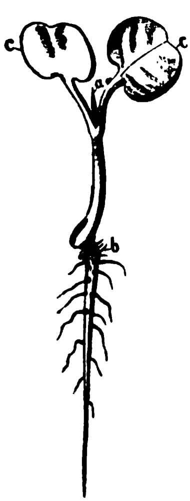

FIG. 88. GERMINATION OF DICOTYLEDONOUS SEED; *a*, plumula; *b*, radicle; *c*, *c*, cotyledons.

time, yielding to the young plant the nourishment they contain. By the time this is exhausted, the true leaves and roots are sufficiently developed, for the support of the structure; and the cotyledons, being then no longer required, decay away. Thus it is seen that, in all the essential points, the history of the young Phanerogamic plant corresponds exactly with that of the young Fern;—the chief difference consisting in this;—that the development of the former, up to the time when its cotyledon or primary frond ceased to support it, is assisted by the nourishment prepared for it by the parent; whilst the latter has no such assistance, but obtains its nourishment from the surrounding air and moisture.

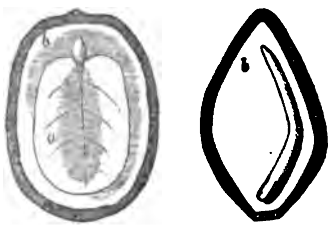

FIG. 89.—SEED OF THE MARVEL OF PERU.

441. The adjoining representation of the seed of the Marvel of Peru, affords an example of a dicotyledonous seed, possessing leafy cotyledons, and a separate albumen; in these, the process of germination is the same, except that the cotyledons only perform the functions of temporary leaves,—the nutritious part of the seed being retained within its coats, until it is exhausted by the young plant.

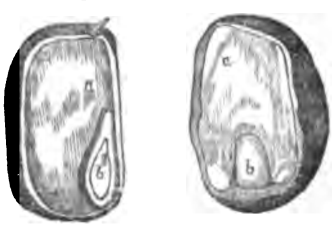

FIG. 90.—SECTIONS OF SEED OF ONION.
a, a, albumen; b, b, embryo.

442. In the seeds of the *Monocotyledons*, the structure of which is illustrated by the accompanying figure of that of the Onion or Lily, the albumen is always separate; and the embryo, which occupies but a small proportion of the whole mass, cannot always be readily distinguished in the midst of it, until germination commences. The cotyledon at first completely sheathes the plumula, which afterwards pierces it, and unrolls its first true leaf.

443. Now it is an interesting fact, that the division of the

Phanerogamia founded upon the structure of the seed, exactly corresponds with that formed according to the structure of the stem;—that is, all Exogens are Dicotyledonous (with only a few apparent exceptions); and all Endogens are Monocotyledonous. Moreover, all the Acrogens, which have no regular method of adding to the diameter of their stem, are destitute of the power of forming true seeds; the germs being, as it were, at once cast upon the world, instead of being reared and cherished by parental care. It has formerly been pointed out, that Exogens, Endogens, and Acrogens, differ also in the distribution of the veins in their leaves (§. 229—32); and it may here be mentioned, that they differ also in the number of parts of which the flower is usually composed. Thus, in Exogens, the regular number of stamens is either *four* or *five*, or a multiple of one of these numbers; and that of the carpels is similar: whilst in Endogens, the number of the same parts is *three*, or a multiple of it. The number of the external or leafy parts of the flower follows the same laws, as will be hereafter explained.

444. The conditions requisite for the germination of the seed, are warmth, moisture, and the presence of oxygen. The process is also favoured by darkness. The influence of each of these agents will be readily understood. No vital action can go on without a certain amount of *heat;* and, where this is not produced within the being, it must be derived from without. The germination of the seed is as much dependent upon warmth, therefore, as the hatching of the egg of a bird; though the amount it requires is not nearly so great. *Moisture* is also evidently required, for the conversion, into a fluid state, of the dry nutriment, which has been previously stored up in the seed; and no change can commence, until this be supplied. The presence of *oxygen* is necessary, because the conversion of starch into sugar requires (as formerly stated, §. 283) that some of the carbon of the former should be set free; and this can only be accomplished, by the union of it with oxygen, so as to form carbonic acid. This process is favoured by darkness, because light has a tendency to produce the contrary change—the *fixation* of the carbon within the structure (§. 286).

445. It is interesting to observe how all these conditions are supplied, in the ordinary course of Nature, by the soil in which the seed is dropped. If it be sown during the spring or summer, it speedily begins to germinate; but if it is deposited in the autumn, it remains almost unchanged, until the winter has passed, and the returning warmth of the air and earth arouses it into activity. It is seldom that the soil is so completely destitute of moisture, for any long time together, as not to be able to excite seeds to germinate; but their sprouting is well known to be favoured by damp weather; and if seeds, through being put into the ground during a drought, remain undeveloped, they are brought forwards very rapidly by a genial shower. A porous soil is to be preferred, on account of the free admission of air, which it gives to a germinating seed; as well as for the other processes of vegetation (§. 178, 9). A stiff clay soil prevents this necessary contact; and thus impedes germination. So complete a check, indeed, may be thus produced, that it has been proposed to bury seeds in clay rammed hard, when it is desired to convey them from one part of the world to another, through very hot climates; the high temperature of which might destroy their vitality, if its influence were not partly prevented, by the bad-conducting power of the mass, in which they are thus enclosed. If seeds be buried very deep, even in a light soil, the contact of oxygen will be sufficiently impeded to prevent their germination; and the bringing such seeds nearer to the surface, will then have as much influence in causing them to sprout, as the supply of either of the agents just mentioned, which might have been previously deficient.

446. The seeds of most Plants are endowed with a remarkable power of preserving their vitality, for an almost unlimited time; if they are placed in circumstances, which neither call their properties into active exercise, nor occasion the decay of their structure. The conditions most favourable for this preservation, will evidently be, a low or moderate temperature, dryness of the surrounding medium, and the absence of oxygen. If all these be supplied in the most favourable manner, there seems no limit to the period, during which seeds may retain their vita-

lity,—that is, their power of performing their vital operations, when placed in the proper circumstances. And even if moisture or oxygen be not entirely excluded, the same effect may result, provided that the temperature be low and uniform. Thus the seeds of most plants may be kept for several years, freely exposed to the air; provided they are not exposed to dampness, which will cause them either to germinate, or to decay. Some of those, which had been kept in seed-vessels of plants preserved in the herbarium of Tournefort, a French botanist, were found to retain their fertility, after the lapse of nearly a century.

447. Instances are of no unfrequent occurrence, in which ground, that has been turned up, spontaneously produces plants different from any in their neighbourhood. There is no doubt that, in some of these cases, the seed is conveyed by the wind, and becomes developed only in spots, which afford it congenial soil; as was formerly mentioned in regard to the spores of the Fungi (§. 50). Thus, it is commonly observed, that clover is ready to spring up on soils, which have been rendered alkaline by the strewing of wood-ashes, or the burning of weeds, or which have had the surface broken and mixed with lime. But there are many authentic facts, which can only be explained upon the supposition, that the seeds of the newly-appearing plants have lain for a long period imbedded in the soil, at such a distance from the surface, as to prevent the access of air and moisture; and that, retaining their vitality under these conditions, they have been excited to germination by exposure to the atmosphere. The following possesses considerable interest.

448. To the westward of Stirling, there is a large peat-bog, a great part of which has been flooded away, by raising water from the river Teith, and discharging it into the Forth;—the object of this process being, to lay bare the under-soil of clay, which is then cultivated. The clergyman of the parish was on one occasion standing by, while the workmen were forming a ditch in this clay, in a part which had been covered with fourteen feet of peat earth; observing some seeds in the clay, which was thrown out of this ditch, he took them up and sowed them; they germinated, and produced a species of Chrysanthemum.

A very long period of years must have probably elapsed, whilst the seeds were getting their covering of clay; and of the time necessary to produce 14 feet of peat-earth above this, it is scarcely possible to form an idea; but it must have been (in the natural course of things) extremely great.

449. The following circumstance, which occurred about 30 years ago in the State of Maine, in North America, is, perhaps, still more remarkable. Some well-diggers, when sinking a well, at the distance of about 40 miles from the sea, struck, at the depth of about 20 feet, a layer of sand; this strongly excited curiosity and interest, from the circumstance that no similar sand was to be found anywhere in the neighbourhood, or anywhere nearer than the sea-beach. As it was drawn up from the well, it was placed in a pile by itself; an unwillingness having been felt to mix it with the stones and gravel, which were also drawn up. But when the work was about to be finished, and the pile of stones and gravel to be removed, it was found necessary to remove also the sand-heap. This, therefore, was scattered about the spot, on which it had been formed; and was for some time scarcely remembered. In a year or two, however, it was perceived that a great number of small trees had sprung from the ground, over which the sand had been strewn. These trees became, in their turn, objects of strong interest; and care was taken that no injury should come to them. At length it was ascertained that they were Beach-Plumb trees; and they actually bore the Beach-Plumb, which had never before been seen. except immediately upon the sea-shore. These trees must, therefore, have sprung up from seeds, which had existed in the stratum of sea-sand pierced by the well-diggers; and, until this was dispersed, in such a manner as to expose them to the air, they remained inactive. "By what convulsion of the elements," adds the narrator, "they had been thrown there, or how long they had quietly slept beneath the surface of the earth, must be determined by those who know very much more than I do."

450. The following is an example of the same general fact, which is interesting from its connexion with historical events. In the year 1715, during the rebellion in Scotland, a camp was

formed in the King's Park (a piece of ground belonging to the castle) at Stirling. Wherever the ground was broken, broom sprang up, although none had ever been known to grow there. The plant was subsequently destroyed; but in 1745, a similar growth appeared, after the ground had been again broken up for a like purpose. Some time afterwards, the Park was ploughed up, and the broom became generally spread over it. The same thing happened in a field in the neighbourhood, from the whole surface of which about nine inches of soil had been removed. The broom-seeds could not have been conveyed by the wind, although the plant is a common one in the neighbourhood, because they are heavy and without wings (§. 471); and the form of the ground is such, that no stream of water could have transported them, or have covered them afterwards with soil. Such an effect must have resulted from the operation of causes, continued through a long period of time.

451. Perhaps the most remarkable instance on record, as presenting satisfactory proof of the lapse of at least 1600 or 1700 years, is one related by Dr. Lindley. "I have now before me," he says, "three plants of Raspberries, which have been raised in the gardens of the Horticultural Society, from seeds taken from the stomach of a man, whose skeleton was found 30 feet below the surface of the earth, at the bottom of a barrow,* which was opened near Dorchester. He had been buried with some coins of the Emperor Hadrian." Corn-grains enclosed in the bandages which envelope the mummies, are said to have occasionally germinated, though most of them seem to have lost their vitality. There is nothing improbable in the fact; but as the Arabs, from whom the mummies are commonly obtained, are in the habit of previously unrolling them in search of coins, &c., it is not always certain that the seeds which have sprouted were really at first enclosed with the mummies.

* These *barrows*, as they are termed, are large mounds of earth, which are very common on the downs along the south coast of England. They are evidently artificial, not natural; and, when dug into, are usually found to contain human remains, with pottery; weapons, &c. Hence they are evidently burial-places; and as a large number of them are generally found together, they seem to have been erected on fields of battle, to contain the bodies of the slain.

452. When a plant is raised from seed, it will always bear a strong likeness to its parent; and if the species be one which has little tendency to variation, it will resemble it very closely. But there are many species, which have a great disposition to present deviations, from what may be considered their original form (§. 13—16); and thus, from the seeds of the same parent, it is often possible to produce, by a difference of treatment, a number of plants differing considerably from one another. Whatever such differences may be, however, these plants are all regarded as belonging to the same species, since they are descended from a common stock; and by such experiments, it may be often shown that plants, which have been considered as distinct species, have no real title to be so classed (§. 16).

453. It is often possible, however, to produce seeds capable of giving origin to plants, that shall combine the characters of two different races. This is done, by placing the pollen of one species upon the stigma of another; so that the germ, furnished by one, shall be nursed (as it were) by the other. It is not difficult to understand, how the germ thus influenced, should be subsequently developed into a form, differing from that of its own parent; for the germs of Cryptogamia, which are not received into any ovule, but are dependent upon the elements alone for their support, are often developed (especially among the lower tribes) into forms very different from that which they would naturally present. Thus a *Mucor*, a sort of Fungus concerned in the production of mouldiness, has been seen growing in water, in a form so like that of a Conferva, that it was only recognised as a Fungus, when it lifted up its fructification above the fluid.

454. The plant developed from a seed produced by the agency of two races, is termed a *hybrid*. It is necessary, in order that the seeds thus formed should be fertile, that the parent species should be nearly allied to each other; and it is very seldom that a hybrid can be produced, when they do not belong to the same genus. Now, if the hybrid bear flowers, and its stigma be fertilised with its own pollen, it may produce seeds that can be raised into plants like itself; and these may flower and produce

a third generation in like manner. But there is no instance in which a hybrid race, which has thus originated in the intermixture of two species really distinct, has ever been continued without intermixture, beyond the fourth or fifth generation. The plant, when not fertile by itself, may bear seed, if its stigma be sprinkled with the pollen of one of its parent species; and its pollen may be fertile, when placed on the stigma of either of these. In this manner, a race intermediate between the hybrid and one of the parent species is produced; and this is continued longer, just in proportion as it is caused to approach the pure breed, by a successive intermixture of this kind. The end of all hybrid races, produced between species really distinct, appears to be, therefore, that—either the race becomes soon extinct, which it will do if kept separate,—or it merges into one of the parent races, if continued by intermixture with either of them. This principle affords a valuable test for determining what really are, and what are not, distinct species; for if a hybrid race can be produced between them, which continues to be fertile of itself, the probability is strong, that they are only varieties. Cultivators of flowers are constantly in the habit of producing such new races, between the different varieties of many plants,—for instance, the South American *Amaryllis* and the *Calceolaria;* both these species are very much disposed to spontaneous variation; and, by selecting the most beautiful of the new races, which spontaneously originate from their seeds, and causing these to produce hybrids, a still larger amount of variety, both in form and colour, may be obtained. These hybrids are of equal fertility with their parents, since the latter are not separated by any really essential difference.

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455. Having now considered the general structure and offices of those organs of Phanerogamia, which are most interesting to the Physiologist, from their connection with the important function of Reproduction, we shall notice those parts of the flower which are less essential to this object, but which commonly excite

more interest, on account of the varied and beautiful forms and colours they present;—namely, its external leafy portion. This may be altogether termed the *perianth*, or floral envelope; the *essential* portion of the flower being, as before explained, the stamens and pistil that occupy its centre, which are sometimes destitute of any protection. The perianth may be regarded as consisting, in its most regular form, of two circles (arranged like the whorls or verticils of leaves) of leafy organs; of which the outer circle is generally green, and the inner one coloured.* Of this outer circle, the leaves or *sepals* not unfrequently grow together, or adhere, at their edges; so that a sort of cup is formed; hence the whole is termed the *calyx* (cup). The inner whorl is termed the *corolla*, and its divisions are called *petals;* they not unfrequently grow together in the same manner (as in the *Campanula* or Harebell) forming a second cup within the calyx.

456. When the Calyx seems formed of but one piece, in consequence of the adhesion of its leafy portions, it is said to be *monosepalous* (possessing but a single sepal); and when the petals have united in a similar manner, the corolla is said to be *monopetalous.*† Though these terms are not strictly correct (since there are really as many sepals and petals in the one case as in the other), they are convenient, and are often employed in describing plants.—The terms *gamosepalous* and *gamopetalous* have been introduced to designate these forms of calyx and corolla; their signification being, that the sepals and petals are united or married at their edges.—The real nature of such a calyx or corolla is shown by varieties, or monstrosities, like that delineated in the adjoining figure; here the regular form of a

* In Botanical language, the term *coloured* always means, that the part is *not green;* green being regarded as no colour in Plants. A *white* flower is spoken of as coloured.

† It is worthy of inquiry, whether it would not be more proper to consider the monosepalous calyx and the monopetalous corolla (and even many of those in which the sepals and petals are distinct), as consisting of so many *leaflets*, or parts of a single leaf; in the some manner as, according to a suggestion formerly made (§. 303, *note*), some verticils probably consist not of a number of leaves, but of a single one, divided into leaflets.

monopetalous corolla, (in which the petals have grown together to form a tube, and are only separate at the top) is shown at *a*; whilst *b* shows the separate condition of the petals, which is occasionally seen as the consequence of a want of adhesion between their edges. Different kinds of flowers, too, exhibit every variety, between the completely-separate and the completely-adherent condition of the sepals and petals; and these differences are often very useful, in distinguishing them from each other.

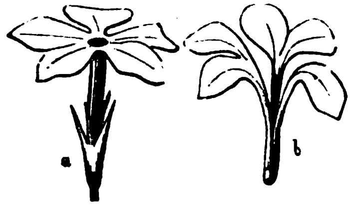


FIG. 91.—*a*, monopetalous corolla; *b*, monstrous form of the same.

457. Outside the calyx, is not unfrequently to be found another whorl of leafy bodies, more resembling in their aspect the ordinary leaves of the plant; these are called *bracts*, and are well seen in the Strawberry, where they surround and alternate with the sepals of the calyx. When no complete circle of them is seen, one or two are often present, and then they are generally larger. They do not always immediately surround the flower; but are often to be found at the bottom of the flower-stalk. In Fig. 92 are shown the Bracts, as they occur in the Lime and Hellebore; in the former case (*a*) we see the base of the flower-stalk sheathed by a single leaf, which closely resembles the ordinary leaf of the plant; in the latter (*b*), we see the flower itself enclosed in similar leaves. In Fig. 93 the bracts of two *umbelliferous** plants are represented; these

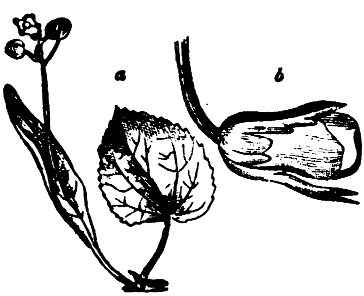


FIG. 92.

* By *Umbelliferous* plants is meant that tribe, in which the flower-stalks

commonly form a whorl of three or more leaflets, where the flower-stem first divides; and other smaller whorls are seen,

FIG. 93.—INVOLUCRE OF A PHLOX AND CHINESE PRIMROSE.

where the second subdivisions take place. Such whorls are usually termed *involucres*. Where a single large bract encloses the flower-stalk and bud before its expansion, this is usually termed a *spathe*. This is seen in the Snowdrop, Onion, Narcissus, &c. The Spathe is peculiarly large in the Palms, where it often has to enclose a large branch loaded with flowers. It is of great size also in the Arum, enclosing the central pillar termed the *spadix*, on which the flowers are clustered; in the common Wake-robin (or Lords and Ladies) of our hedges, this spathe is green; but in

FIG. 94.—SPATHE OF NARCISSUS AND ARUM.

divide and subdivide in such a manner as to produce the peculiar form termed an *umbel*, which is seen in the Hemlock, Carrot, Parsley, &c.

some exotic species, cultivated in our drawing-rooms, it is white, and is commonly regarded as the flower. These bracts may be regarded, as establishing the transition of form and structure, between the common leaves of the plant, and those modified or metamorphosed leaves, which form the perianth. Sometimes they can scarcely be distinguished from the former; whilst in other cases, they are brightly coloured, and more closely resemble the latter; and, in the *Hydrangea* and some other plants, they really constitute the most showy portion of the flower; being very large and brilliant, whilst the flower they enclose is so small, as to be almost overlooked. In many instances, the bracts form so gradual a transition, between the true leaves and the parts of the flower, that it is very difficult to say where the former end and the latter begins. This is the case in the double Pæony,—a plant now very common in gardens. Its lower leaves are very complex in their structure, being divided into a great number of segments (§. 235); in tracing them up the stem, they are found to become simpler and simpler in their character as they approach the flower, and also to diminish in size; and at the same time, their spiral arrangement round the stem becomes more evident, the intervals between them being diminished. In this manner, they may be at last traced into the outermost whorl of the leafy parts composing the flower; and it is quite impossible to specify the exact place, at which the true leaves may be said to end, or the calyx to commence.

458. From this it would appear, that there is no *essential* difference between the sepals of the calyx and regular leaves; and examination of their structure bears out the conclusion. If we take an example from a plant, in which the sepals are distinct from each other, and green, we should find it difficult to assign any important characters, in which they differ from leaves. They possess two layers of cuticle, furnished with stomata; having green cellular tissue or parenchyma between them, supported by veins consisting of woody fibre and vessels. There are many cases, however, in which the calyx is brightly coloured, equalling the corolla in beauty, and even surpassing it in brilliancy. In the Lilies and Tulips, we find the perianth composed of six

coloured parts, which seem to spring at once from the flower-stalk, without bracts or calyx. But, if they be examined, it will be found that three of these arise lower down than the others, and therefore partly enclose them; so that these three are to be regarded (in spite of their colour) as sepals of the calyx; and it may often be observed that, though coloured in their interior, they are greenish outside, especially along their middle. In the Fuchsia,—a beautiful plant which may now be grown with little difficulty in our gardens, though formerly considered a rare exotic,—the calyx is even more brightly coloured than the corolla. This change of colour, however, by no means disproves what has been said of the analogy between sepals and leaves; since, as formerly noticed, leaves themselves occasionally undergo similar changes; and the colouring principle seems to consist, in all cases, of nearly the same substance, in different states of chemical combination (§. 386). Further, the calyx not unfrequently returns to the form of true leaves, in flowers in which its regular appearance is very different; such irregular formations, which are termed monstrosities, are in this, as in many other instances, very instructive to the Physiologist, in leading him to the knowledge of the true character of organs, of which the external form may have been greatly changed.

459. Similar remarks may be made upon the real nature of the petals of the Corolla. They are almost always coloured; but they still preserve their leafy structure, having cuticle, stomata, parenchyma, and veins. It has been seen that, in the Tulip and Lily tribe, there is no essential difference between the sepals and petals; what is true of the former, therefore, must be also true of the latter. Further, in the Pæony, the transition from the form of the sepal to that of the petal, is as gradual as that from the ordinary leaf to the sepal. If we trace the portions of the perianth from without inwards, we may observe that the green leafy sepals are slowly changed, in the first place by having their points and edges turned from green to pink, and becoming more delicate in their structure;—next the inner side is seen to be completely coloured, while the back is still greenish in its centre; and finally the whole is converted into an ordinary

petal. But even where the appearance of the petals is the furthest removed from that of ordinary leaves, it is very common to find monstrosities, which show that there is no essential difference. The common Wood-Anemone, for example, not unfrequently presents several varieties in the character of the sepals and petals, intermediate between what may be regarded as natural to them, and that of the ordinary leaves. Thus, the calyx may be converted into a whorl of true leaves, whilst the white petals have become green and resemble the ordinary sepals; or the metamorphosis may have proceeded farther, and the petals, as well as the sepals, may have been converted into ordinary leaves.

460. The structure, appearance, and functions of the Stamens are so different from those of the parts of the perianth, that it would scarcely appear probable that *they* too are transformed leaves; and yet this will prove to be the case. There are many flowers, in which the transition from the form of the petal to that of the stamen, is as gradual as those already described. This is the case, for example, in the Pæony; and it is still more evident in the common White Water Lily, the principal stages of transformation in which are represented in the adjoining figure.

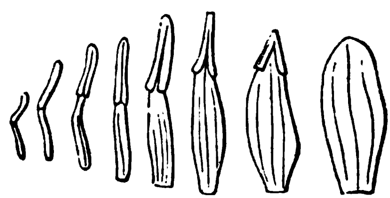


FIG. 95.—STAGES OF TRANSFORMATION OF PETALS OF WHITE WATER LILY, INTO STAMENS.

The petal, *a*, is first thickened near its point, as seen at *b*, by a deposit of yellow substance, which, when examined, is found to be pollen. This thickened part gains upon the expanded portion of the petal, which becomes contracted in a corresponding degree, as we advance nearer the centre of the flower; until we arrive at the regular form of the stamen, *d*, in which we observe that the two thickened parts have met as anther-lobes, and that the leafy portion of the petal is contracted into the filament supporting them. The inner rows of stamens (of which there are several) are still more contracted, not being

fully developed; and here we lose all trace of the leafy appearance.

461. Although the usual appearance of the stamens is such as was formerly described, there are several flowers in which they ordinarily have very broad expanded filaments; and these organs are subject to the same kind of transformation into the leafy character, as are the portions of the calyx and corolla. The transformation of stamens into petals, in fact, is extremely common; it being generally in this manner that *double* flowers are produced from single ones. In the wild Rose, for example, we find but a single row of petals, surrounding a very large number of stamens; whilst in the cultivated Rose of gardens, there are several rows of petals, and the number of stamens has proportionally diminished. The Rose is a flower, which is very liable to produce monstrosities or irregular growths; and it is not uncommon to find this transformation more complete,—the stamens, as well as the petals and sepals, being converted into true leaves, so that the flower is entirely green. The same is often the case with the Wood-Anemone. No further evidence then, is required to prove, that the *elements* of the leaf and the stamen must be the same (although their fully-developed forms are so different); and that these elements may be developed into one form or the other, according to circumstances, with which we are as yet only in part acquainted.

462. We now come to the Pistil, which occupies, as formerly stated, the centre of the flower. In considering its real nature, it is always necessary to regard it as made up of a number of separate *carpels* (§. 434), whether or not they can be completely distinguished;—just as the gamosepalous calyx and the gamopetalous corolla are considered as formed, by the adhesion of their several constituent portions. We have to examine, then, what is the real character of each carpel; and this is sometimes manifested to us in a remarkable manner. When the carpels are distinct, and are fully developed, they not unfrequently present a very leafy appearance. Thus, the pod of the Pea, when opened, is seen not to differ essentially from what a leaf, with its two edges rolled together, would be; the prolongation of the

stalk corresponds with the midrib, and the two valves of the pod are the two lobes of the leaf. Instances occasionally present

FIG. 96.—MONSTROSITY IN THE PEA; THE EDGES OF THE CARPELS NOT UNITED.

themselves, in which this is seen more decidedly, from the want of development of the ovules, and the non-closure of the pod, so that its leafy aspect is less departed from. There are little projections, however, from the thickened edges of this *carpellary leaf*, which show where the ovules should have been. A still more interesting monstrosity is almost constantly presented by the double Cherry. The centre of the flower is occupied by a small leaf in place of the usual carpel. This leaf (Fig. 97, *a*) has the two edges folded towards each other, and the midrib is greatly prolonged, having a little dilatation at its summit. If this be compared with the carpel of the cherry, seen at *c*, no doubt can be entertained that the two sides of the leaf answer to the walls of the ovary, the prolonged midrib to the style, and its dilated extremity to the stigma. In some instances the flower contains two

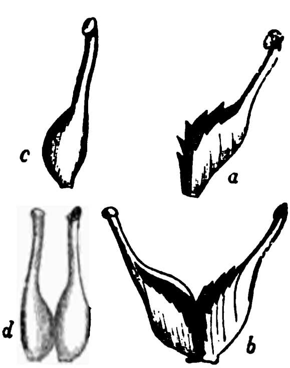


FIG. 97.

such leaves; and they are then always seen to present their hollowed faces towards each other, in the manner seen at *b*. This precisely corresponds with the position of the true carpels shown at *d*; in which the *suture* or line of junction of the two edges, of each carpel is opposite to that of the other. If any further proof were required, of the carpel being a transformed leaf, it is afforded by the fact that, in Roses, Anemonies, Ranunculuses, and other such flowers, which are liable to have their stamens converted into petals, or into true leaves, the carpels not unfrequently undergo the same changes, so that the whole flower is metamorphosed into a bunch of leaves, which are still arranged, however, on exactly the same plan with the parts of the real flower.

463. The usual arrangement of these parts corresponds precisely with what was formerly stated, of the disposition of the leaves (§. 303.) When the spiral, which may be regarded as their regular mode of arrangement, is converted into a whorl or verticil, by the non-development of the intervening part of the axis, and two or more of these whorls succeed one another, their several leaves do not correspond, in the direction in which they issue from the stem; but are so placed, that the leaves of each are above or below the *intervals* between the leaves of the other. When this is the case, the whorls are said to *alternate* with each other.—Now the regular flower may be considered as made up of five such whorls, arising from nearly the same part of the axis; and they are disposed alternately with each other. Thus, the sepals of the calyx *alternate* with the bracts; the petals of the corolla alternate with the sepals, and are *opposite* to the bracts; the stamens alternate with the petals, and are opposite to the sepals; and the carpels alternate with the stamens, and are opposite to the petals.

464. This very simple law, regulating the position of the parts of the flower, is apparently subject, however, to many exceptions; but these all arise from the interference of other causes. For example, the number of parts may be so much increased, that they cannot be all arranged in one whorl, and they then form additional verticils; which, however, still follow the

same principle of arrangement. For example, the adjoining figure shows a plan (*a*) of the flower of a Cherry; in the outer circle are marked the places of the five sepals, and in the next those of the five petals which alternate with them. Within these, however, we find no less than twenty stamens; but these may be regarded as composing four whorls with five in each, apparently blended together, however, by the closeness of their origin. The other diagram (*b*) is the plan of the flower of a Squill; in which, as in other Endogens, the parts are disposed in *threes* not in fives. The outer circle has three dots indicating the places of the three sepals; and on the inner one the petals are indicated in like manner, and are seen to alternate with the former; the stamens are six in number, and distinctly form two rows, of which the outer one is opposite to the whorl of the calyx, and the inner one to that of the corolla; and with this, again, the carpels would alternate.

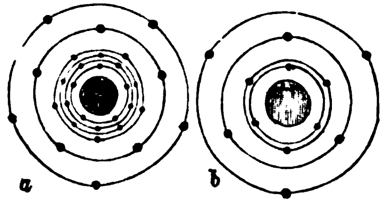


FIG. 98.—PLANS OF FLOWERS: *a*, Cherry; *b*, Squill.

465. An apparent irregularity, however, is more frequently produced by the absence of some of the parts. Thus, in the Primrose, there are five sepals, five petals, and five stamens; but the stamens are opposite to the petals, instead of alternating with them (Fig. 99; *a*). Now the explanation which the Botanist would offer of this irregularity, is,—that there must be a row of stamens intermediate between the petals and the stamens, which, from some cause, have not been developed. And this is found to be really the case; for in the Samolus, a plant otherwise formed upon the

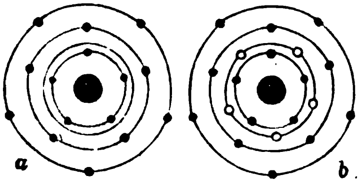


FIG. 99.—PLANS OF FLOWERS: *a*, Primrose; *b*, Samolus.

same plan as the primrose, five little scales, which are partly-developed stamens, appear in the situation of the absent row. In the Sage, again, we find a calyx of five sepals, and a corolla of five petals; but only two stamens are seen within (Fig. 100, *a*). Now, upon looking attentively at the inside of the tube of the corolla, two little scales are often to be seen growing in the place, where two of the deficient stamens should have been,—that is alternating with the petals; these two scales are frequently developed as perfect stamens, in flowers which are otherwise constructed exactly like the Sage (*b*); and even the fifth makes its appearance in some instances, exactly where it should regularly be found. Such deficiencies are often to be noticed; thus in the genus Bauhinia, which has, properly, ten stamens arranged in two whorls, there are some species in which only three perfect stamens are developed (*a*), or even but a single one (*b*). Deficiency in the number of carpels in the pistil, is even more common; and it is in fact rare to find a flower, which presents a structure that may be considered perfectly regular, as well in its form as in the number of its parts. Without forming some such standard, however, it would be impossible to obtain a definite idea of the nature of the deviations, of which some of the principal kinds will have to be presently considered.

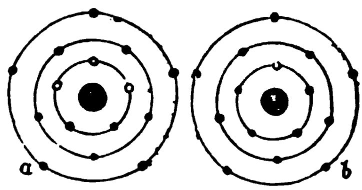


FIG. 100.—*a*, plan of flower of Sage; *b*, development of stamens in allied genus.

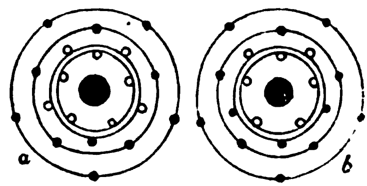


FIG. 101.—PLANS OF FLOWERS OF BAUHINIA.

466. One of the commonest of these deviations is that, in which the calyx appears to arise, not, as is usual, below the ovarium, but above it. In this case it will be found, that the real position of the parts is the same; but that the perianth wraps round or encloses the ovarium, and spreads itself out only when

freed from it. The stamens too, not unfrequently seem to arise from the corolla, instead of from the axis of the flower; but this effect is produced in a similar manner—namely, by their adhesion at their lower part, to the inner side of the petals. The stamens, again, sometimes adhere to each other, so as to form a complete tube, surrounding the pistil.

467. In the foregoing instances, the *symmetry* of the flower is not destroyed; that is, it may be divided into two similar halves by a line crossing it in any direction. But there are many irregularities resulting from the unequal development of the different parts of the same whorl, and from the adhesion of these parts to each other in various ways; so that the whole form of the flower sometimes appears completely changed, and there is only one direction, in which it can be divided into two equal halves. This is the case in the flower of the Pea or Bean, for example; in which, as in other plants of the Papilionaceous group (so named from the resemblance of the flower to a Papilio or Butterfly), there is one broad petal standing erect,—two separate ones termed the wings, which are prolonged from its base,—and two others united together, forming what is termed the keel, which is enclosed between the last.

468. The flower is usually placed at the end of the flower-stem, or of its subdivision of it; and the tendency in this stem to lengthen, appears to be checked by the development of a flower-bud. It commonly swells out at the insertion of the perianth, forming what is called the *disk* or *receptacle;* and in this, as formerly stated, nourishment is frequently laid up, in the form of starch, for the development of the young ovules (§. 285.) This receptacle sometimes grows upwards between the carpels, and even encloses them. In other cases, it extends so much, as to separate the carpels from one another; this is the case in the Strawberry, of which the fruit is the swollen receptacle, whilst the little bodies scattered over its surface (commonly termed seeds) are in reality the carpels. Sometimes, however, it happens, that the flower-stem continues to grow between the points, from which the solids proceed; and they are then separated from each other, just as are leaves in like circumstances (§. 304). The spiral

line, in which the different parts of the flowers are inserted round the axis, then becomes very evident. This is not unfrequently the case in the Double Tulip, as well as in some Euphorbiums (Spurges); and as the parts of the flower are generally at the same time more or less changed into the leafy character, the resemblance of the whole flower to a leaf-bud or undeveloped branch then becomes very obvious. Sometimes after giving off the whorls of the perianth, the flower-stalk is prolonged through their centre, and bears another bud at its extremity; this is by no means uncommon in Roses. It is well known to Gardeners that, by a still further change, flower-buds may be actually converted into leaf-buds, and developed into true leaf-bearing branches; a fact which sufficiently proves, that every part of the flower is formed out of the same elements with leaves, and that the development of either may take place according to circumstances. Hence we know why a difference in the amount of nutrition which the plant receives, should influence its tendency to the production of flowers and fruit. It has been stated that, in each of the parts of the flower, there is a tendency to revert to the leafy form; and this is especially the case with the stamens, which are often converted into petals (thus changing a *single* flower into a *double* one), when the plant is transferred from the poor soil, in which it may be naturally growing, into the rich mould of a garden. Now if a plant be over-supplied with nourishment, it will *run to leaf*, as it is termed,—that is, it will develope too many leaf-buds, and will not put forth flowers; so that, in order to make it bear fruit, it is necessary to diminish its quantity of sap; one method of effecting which, is to dig a trench at a certain distance round the bottom of the trunk, so as to cut off part of the supply it receives from the roots.

469. It might be objected to the statements here made, that the pollen and the ovules are so different from anything which the leaf naturally produces, that no analogy can be imagined between organs bearing these, and the ordinary leaves. But, if the structure of the pollen-grain be considered, it will be perceived to correspond precisely with that of other cells of cellular tissue; differing chiefly in its power of separating itself from the

rest, and of sending forth little granules which are to form new plants, instead of adding to the number of cells in the parent structure. Every cell of the Confervæ, it will be recollected (§. 424), may be regarded as essentially a pollen-grain; and therefore the difference cannot be really so great as it appears. Further, in regard to the ovules, the fact heretofore mentioned (§. 240) that certain leaves have the power of producing little buds from their edges, becomes of great interest; for, if the ovules could be regarded as at all analogous to buds, it is evident that their situation on the edges of the carpellary leaf would quite correspond with that of the buds of the *Bryophyllum*, or of the Bog Orchis. And it has been proved by the occurrence of some curious monstrosities, that this is a real analogy; for a seed-vessel of Mignionette has been known to bear a set of little buds at the edges of its carpellary leaves, arranged just as the ovules should have been.

470. We have in the last place to consider the structure of the Fruit, which is the mature or ripened ovary containing fertilised seeds. This frequently differs remarkably from the ovary, which the centre of the flower contained, both in its external appearance, and in the arrangement of its interior. For example, the Cherry, Plum, Almond, or other stone fruit, is formed by a remarkable change in the substance of the carpellary leaf; the internal surface of this becomes hardened into the stone, whilst the external remains as a thin cuticle or skin; and the pulp of the fruit is formed, by the increase of the parenchyma or fleshy tissue of the leaf. Here each carpel originally contained several ovules, but only one of them is usually developed. In the ovary of the Chesnut, there are originally seven carpels or cells with two ovules in each, whilst the ripe fruit consists of but one cell and one seed; so that no fewer than six cells and thirteen ovules are suppressed, in order to enable a single ovule to grow and be matured. It is not uncommon, however, to find two or even three Chesnuts within a single shell, separated by slight partitions. The fruit of the Orange, as formerly mentioned, consists of the carpels, surrounded by the external coat of the ovarium; and having the space between their inner wall and the seeds they

contain, filled up with a very succulent cellular tissue. On the other hand, in the Apple, the carpels lie in the centre of the fruit, and their walls are somewhat horny; the fleshy substance of the fruit is formed by the calyx, which is adherent to the exterior of the ovary; and the parenchyma between its two surfaces swells out in ripening, in the same manner as does that of the carpellary leaf of the Plum. In the Medlar, the carpels have a hard or bony covering, and they lie separately in the midst of the pulpy envelope, which they acquire in like manner from the calyx. In the Strawberry, as just now mentioned (§. 468), the carpels are separated from each other by the receptacle, the expansion of which forms the fleshy part of the fruit. In the Raspberry and Blackberry, on the other hand, the receptacle is the white fleshy stalk which occupies the centre of the fruit; and the pulpy portion consists of the carpels enclosing seeds. The Custard-Apple of the West Indies is formed on this

FIG. 102.—ANONA SQUAMOSA, OR CUSTARD-APPLE: *a*, the flower; *b*, fruit; *c*, the same in section, showing the position of the seeds; *d*, seed; *e*, section of the seed.

last plan; the edible portion consisting of the fleshy carpels which are attached to a slender receptacle. The pods of the Pea, Laburnum, and other Leguminous plants, again, are single carpels, which sometimes grow to a great length, and contain many seeds. In the Bread-fruit (Fig. 103) and Mulberry, the edible portion is formed by the cohesion, into a single mass, of the floral envelopes and ovaria of a large number of flowers, arranged on a central fleshy column or spike. In the Fig. on the other hand, the fleshy receptacle encloses the flowers, which are situated in the interior of the fruit. A great many more varieties might be enumerated; but the mention of these will serve to give an idea

of the mode, in which the very curious transformation of the ovary into the fruit takes place.

FIG. 103.—ARTOCARPUS INCISA, OR BREAD-FRUIT.

471. When the seeds are ripe and ready to be dispersed, the carpel usually splits either along the suture, or in the opposite direction, in order to set them free. There are many curious provisions for their dispersion to a great distance from the parent. Some of these, depending on the movements of the capsule, have already been explained. Many seeds are *winged*, that is, are furnished with a little expansion on each side, fitted to catch the wind; and thus they are wafted to places far distant from those in which they were produced. A very common provision is that of which the Dandelion seed is an example. This, as is well known, is furnished with a very light downy appendage, by which it is floated along with the slightest breath of air; this appendage is nothing else than a peculiar form of the calyx, which remains adherent to the seed, until it is deposited in the soil. Other seeds, again, are conveyed by the waters of streams and rivers, into which they fall; and take root, when left by the current upon a congenial soil. Some are even capable of resisting the influence of the waters of the sea; and in this manner it is, that the coral islands, which are gradually appearing above the sur-

face of the Pacific Ocean, are speedily covered with a crop of luxuriant vegetation. Birds, too, are very important agents in diffusing the various species of plants; some of which are scarcely dispersed in any other way. They carry off the whole fruit to a convenient place, and drop the stone when they have eaten the pulp; or they eat the whole, and the seed, being undigested on account of the hardness of its coats, falls into the ground when voided by them. Some seeds will not readily germinate, until they have undergone this process. When it is considered that from a single seed as many as 30,000 or 40,000 new individuals of some species may be produced in a single year, it will be perceived how abundantly the Creator has provided for the continuance of their race, and how unlikely is their extinction, without some great convulsion of Nature.

472. The Reproductive System of Vegetables, then, counteracts in its operation the effects which would otherwise speedily result from the law, which the Creator has impressed on all organized structures;—that law of limited duration, which renders their death and decay as complete a portion of the series of actions they exhibit, as are the wonderful phenomena in which they are concerned during life. By this counterpoise, all limit to the continuance of *races* is removed, except such as is interposed by some causes beyond. The records of the history of the Earth, which are brought to light by an examination of the rocks that appear at its surface, afford abundant evidence, that vast convulsions must have formerly occurred, involving the Vegetable as well as the Animal kingdom; and that, at each of these, many races of Plants were utterly destroyed; so that there is now probably not a single species remaining, of those which first covered the dry land with verdure, when it was lifted from the depths of the ocean by Almighty Power. Such a convulsion will again occur. A time is foretold when "the elements shall melt with fervent heat, and the earth also and the works that are therein shall be burned up." But the immortal soul of Man will survive this general conflagration, and his faculties will receive that full development, for which his present existence is but a state of preparation.

ADDENDUM.

The third Edition of Professor Liebig's Agricultural Chemistry, recently published, contains much additional evidence in support of the view entertained by him, and embodied in Chap. VI. of the present Treatise,—that the relative fertility of different soils depends, in great degree, upon the supply they yield of the *mineral* ingredients, which are required by the crops of vegetables raised upon them.

It has been already shown (§. 186) that the *carbon* of plants is derived rather from the atmosphere than from the soil; the latter having for its chief purpose, to afford a supply to the young plant, which is repaid with interest, when its full growth has been attained, by the fixation of carbon from the air through the leaves; so that the quantity of carbon in a soil, which supports a flourishing vegetation, is continually increasing rather than diminishing. By similar observation upon an extended scale, it may be shown that their *nitrogen* also is chiefly derived from the atmosphere. For centuries past, a very large quantity of cheese has been annually exported from Holland, the produce of the cows fed upon its pastures. Now the fertility of these pastures has not diminished, but has rather increased; notwithstanding the withdrawal of so large a quantity of a highly-azotised substance, the *casein* or cheesy matter. The cows are permitted to remain on the pastures day and night; and they thus return to the soil, in their solid and fluid excrements, nearly all the *mineral* matter which has been withdrawn from it, with a considerable proportion of the elements of its organic compounds. The nitrogen as well as the carbon removed from it, whether in the form of milk, animal flesh, or the products of respiration imparted to the atmosphere, must be again obtained by the soil from the atmosphere; since there is no diminution in the amount of these elements through a long period of time. But if the mineral matters, which cannot be obtained from the atmosphere, were not restored in the manure, a rapid diminution in fertility would certainly ensue; this having occurred in many similar cases.

It appears from recent chemical analyses of various kinds of

vegetable substances, that we are not to suppose that Wheat and other kinds of Corn require more nitrogen, than do the herbaceous plants raised for the support of cattle. The following table shows the proportion of nitrogen to carbon in the *entire plants* of different species ordinarily cultivated.

With every 1,000 pounds of carbon, we obtain—

From pasture-land, in	Grass	32·7	pounds of carbon.
From cultivated fields, in	Wheat	21·5	,,
,, ,,	Oats	22·3	,,
,, ,,	Rye	15·2	,,
,, ,,	Potatoes	34·1	,,
,, ,,	Beetroot	39·1	,,
,, ,,	Clover	44	,,
,, ,,	Peas	62	,,

The proportion of nitrogen is much greater in the *seeds* of the Corn-plants, in which is concentrated most of the azotised matter, which is elsewhere diffused through the entire structure. It is by far the highest in Peas and Beans; which are nevertheless grown advantageously between Wheat-crops, and which do not require any animal manure thus showing that they do not exhaust the soil of its azotised matter. But the general principle formerly stated (§. 213), respecting the influence of manures, which readily yield carbonic acid and ammonia, in accelerating the growth of plants, and rendering it more luxuriant, is not affected. Still the manures which are richest in this respect will be totally inefficacious, if there be not at the same time an ample supply of the mineral ingredients, which the particular species of plant requires.

It has been mentioned (§. 200—207) that the chief of these ingredients are Silex, the Alkaline Carbonates, and Phosphate of Lime; and recent observations show, that it is chiefly in affording an increased supply of the two first, that the good effects of burning a stiff clayey soil, and of manuring it with lime,—two processes which have long been advantageously practised,—really consist. Owing to the habit which prevails in this country, of allowing the excrements of man to run to waste, instead of committing them again to the soil, a very large quantity of phosphate of lime is continually being withdrawn from it; and if it were not for the great importation of bone-earth from foreign sources, the amount of corn grown in this country would rapidly diminish, for want of this most important ingredient. It has been suggested by Professor Liebig, that the large beds of fossil excrements (coprolites), which are found in some parts of Britain, might be advantageously resorted to for the needed supply.

CHAPTER XIII.

GENERAL PRINCIPLES OF CLASSIFICATION.

473. THE term BOTANY is properly applicable to the whole of the science which includes the study and investigation of the Vegetable Kingdom. Hence the examination of the internal structure of Plants, and of the various processes concerned in their growth and reproduction,—to the description of which, under the title of Vegetable Physiology, the former part of this Treatise has been devoted,—strictly constitutes but a branch of the Science of Botany, and may be designated Structural and Physiological Botany. But by those who have made the study of the Vegetable Kingdom a means of interesting recreation, rather than a professed object of pursuit, and even by some who have considered themselves scientific Botanists, this branch has been entirely overlooked: and the whole attention has been devoted to the other department of the Science, which concerns the arrangement or classification of the many thousand species (§. 15) of Plants existing on the surface of the globe, into groups or divisions; each of which includes a number of species, that have certain characters in common, and that differ from those of other groups. The advantages of such a plan, in the saving of time and labour, are obvious. If all the peculiarities of every species of plant had to be studied and recollected by themselves, it would require a long acquaintance and a retentive memory, to become master of the characters of the 1400 or 1500 species of Flowering-Plants which our own country produces; and when this number is multiplied by a hundred, which it probably must be to represent the amount of species existing on the entire globe, it is obvious that no single mind could be capacious enough to grasp the vast amount of detail thus accumulated.

474. It is the business of the Botanist, therefore, in the first

place, to *collect* Plants from all sources open to him; and he then arranges them according to their species. Thus, we will suppose that he has collected all the plants of Great Britain, and that he has obtained a corresponding series of the plants of France. Upon bringing them together, he would find that many species are common to the two countries; but that some are peculiar to Britain, others to France. If he obtained, in addition, a collection of Spanish plants, he would find that some of the species common to Britain and France are contained in it also; and that some species not known in Britain are common to France and Spain; but he will find many peculiar to Spain. Proceeding thus over the whole world, he would gradually increase his number of new species; at the same time adding considerably to the number of specimens of some which he would find very extensively diffused. He would find a few similar species almost everywhere,—these being the kinds most capable of adapting themselves to varieties in soil, climate, &c.; whilst, on the other hand, he would find many of a very limited distribution,—being restricted to some small extent of country, in which alone they can find the conditions necessary for their growth.

475. The greatest difficulty in this part of the investigation consists in the discrimination of *species* really distinct,—that is to say, of races which have maintained their distinctive peculiarities, so constantly, that they must be considered as having had originally different stocks,—from those *varieties* (§. 16), which may often present differences really greater in amount than those which exist between many undoubtedly distinct species, but which all sprung from the same original stock. Thus, for example, a collection of plants from different parts of India would contain many specimens presenting such marked differences, that the inexperienced Botanist would not hesitate to set them down as distinct species; yet to one who has carefully examined the subject, and has made himself acquainted with the variations produced by the differences in soil and climate so striking in this extensive tract, it becomes apparent that they are all members of the same. There is, too, in many species a remarkable tendency to run into *spontaneous* variations, for which no exter-

nal influences will account. Thus the seeds of the same individual of the beautiful *Fuchsia*, now naturalised in our greenhouses and in the open air of the milder parts of Britain, have been known to produce plants, whose flowers differ so much in shape and in the proportional length of the calyx and corolla, that, if these had been collected and compared without the knowledge that they had been produced from one plant, they would have been regarded as distinct species, perhaps even (so striking is the difference) as distinct genera. Nearly the same is the case with another South American Plant now much cultivated in Britain,—the *Calceolaria* or slipper-shaped flower; of which an immense number of varieties, differing widely in the shape as well as the colour of the flower, are now known, almost every Horticultural Exhibition having a new one: and the beautiful South American *Amaryllis* has a like tendency, of which the gardener has taken similar advantage.

476. Hence in discriminating what are real species from what are simply varieties, the Botanist is treading on very insecure ground, until he has ascertained, for every species, its tendency to run into varieties of form, whether spontaneous, or induced by change of external conditions. His greatest difficulty arises from those cases, in which have arisen what are termed *permanent varieties*, which reproduce themselves with the same regularity as do real species. An instance of this in the Animal Kingdom is that of the different races of men, which are respectively distinguished by marked peculiarities, that are regularly repeated through each generation; so that many naturalists have been inclined to regard them as really distinct species. There is, however, good evidence (independently of the Mosaic History) to prove that they have all descended from a common stock. Precisely the same is the case in regard to Plants; many races of which, even in Britain, are still under discussion amongst Botanists; some maintaining that they are distinct species, and others that they are but varieties. Thus of the Willow, 71 species have been stated by one authority to exist in Britain, whilst another reduces them to 29. The genus Rubus or common Bramble has been thought to contain 21 British species,

which are probably reducible to 6 or 8. These details are here introduced, for the purpose of putting the young Botanist on his guard, against the tendency to multiply species, which is now prevalent among superficial writers, and which is still further encouraged by Gardeners, who give new specific names to such varieties as those just alluded to, and even to *hybrids* between these (§. 454).

477. When the Botanist has satisfied himself regarding the species which he has collected, his next step is to combine those amongst which he finds the greatest resemblance, into *genera*. Now in this process he must not be altogether influenced by similarity in their general external aspect; for this will often conceal great differences in their most important organs. There are certain parts which furnish *essential* characters, without similarity in which it would be wrong to associate species, however alike in other respects, in the same genus; and, on the other hand, there are parts so susceptible of variation, that the differences between them must be very striking indeed, to warrant the plants being arranged under different genera, when they agree in what have been termed the essential characters. Thus, for instance, the general outline of the leaf has been stated to be often subject to great variety, in accordance with the degree in which the space between the veins is filled up with fleshy parenchyma (§. 234, 5); and in most cases, a difference in the outline of the leaves of two plants, the distribution of the veins remaining the same, would not alone serve to cause two plants exhibiting it to rank even as distinct species. But any considerable alteration of the veining would be held sufficient for such a separation; though the two plants, if agreeing in the structure of their organs of fructification, would still be placed in the same genus. On the other hand, a marked and constant difference in the organs of fructification would be rightly held sufficient to place the two species in different genera, even though the form and veining of the leaves might be precisely the same. On the relative value of the characters furnished by the different organs more will hereafter be stated.

478. Even when thus grouped together into genera, however,

the number of objects, which the Botanist has to study, remains by far too great for convenience; and he next forms his genera into *orders*, and combines these orders into *classes*, according to their respective correspondence and difference in certain characters of a still more general nature. Now in this process he may follow two very different plans; and upon these are founded the two systems of classification which are now in vogue. One of these is termed the Linnæan System, after its founder; or the Artificial System, from its character: the other is termed the Natural System. In the Linnæan System, a small number of characters—chiefly the number of stamens and pistils—is taken as the standard; and the whole Vegetable Kingdom is distributed under classes and orders, according to the correspondences and differences among the several genera in these respects,—no regard whatever being had to any other characters. In the Natural System, *all* the characters of the genera are studied; and those are united into orders, which present the greatest correspondence in the characters that are regarded as of the most importance: on the same principle, the orders are united into classes. If the former plan be followed, genera most widely differing in their structure and physiological characters are often brought together, and others which are nearly allied are frequently separated to a great extent; so that in fact, it is very common to find, that nothing can be stated as true of all the plants included in a Linnæan order, except that they have a similar number of stamens and pistils. On the other hand, in the Natural System, the number of characters, in which there is a general agreement among all the plants of a particular order, is so great that, to say that the plant belongs to a certain order, is at once to give the greater part of its description. This is the case also in the highest or most general groups. For instance, to say that a particular species is an Exogen, is at once to make known the structure of its stem and the mode of its increase,—to express the important fact that it has two cotyledons or seed-leaves,—to render it most probable that the arrangement of the veins in its leaves is reticulated rather than parallel,—and to intimate that the parts of its flowers are likely to be arranged in fives or fours, rather than in threes.

479. There is a point of agreement among the plants brought together in Natural Orders, which is of the greatest practical importance. This is, that those which agree in structure almost invariably correspond in *properties* also. For instance, the whole of the Papaveraceæ or Poppy tribe possess narcotic properties; all the Ranunculaceæ or Crowfoot tribe are acrid; whilst all the Malvaceæ or Mallow tribe are destitute of unwholesome properties. Thus, when a plant is recognised as a member of a particular Natural Order, an almost certain account may be given of its properties,—whether it is likely to be injurious or wholesome, to furnish valuable medicines, or important articles of food. It must be remembered, however, that the peculiar properties of the plant do not pervade every portion of it; and that it may hence be possible to obtain wholesome nutriment, even from members of orders most distinguished for their deleterious properties. Thus the Potato belongs to the order Solaneæ, which contains the Deadly Nightshade, Henbane, and other poisonous plants; but the edible part of it, which is a deposition of starch for an express purpose (§. 337), is free, or nearly so, from the narcotic properties which exist in the stems and leaves. Indeed, as a general rule, such depositions of starch may supply wholesome food in any order, more especially if care be taken to free them from any juices they may contain; thus the Cassava, which furnishes one of the most important articles of food to the inhabitants of many tropical countries, is obtained from a plant of the order *Euphorbiaceæ* or Spurge tribe, which is distinguished for its very acrid qualities: and these are principally restricted to the juice expressed from the meal after it has been ground.

480. The Linnæan system, however, is not without its advantages for particular purposes. To a person commencing by himself the study of Systematic Botany, desirous of making himself acquainted with the names and characters of the plants he may meet with in his walks, and not ambitious of extending his studies to the higher parts of the science, the Linnæan system, when applied with the aid of books, possesses facilities which are (at present at least) greatly superior to those afforded by the other, and which are well calculated to encourage a learner. To count the number of stamens and pistils is generally a very easy

process; this at once establishes the class and order; and nothing then remains, but to determine the genus and species, which (among the comparatively small number found in Britain) a little practice in the examination of characters will enable any intelligent person to do, with the aid of books in which these are laid down. The habit thus gained of discriminating characters, and of applying terms, is a most valuable preparation for the study of the Natural System when opportunity presents itself. It must be constantly borne in mind, however, that the utmost use which can be made of the Linnæan system, consists in the assistance it affords in the discovery of the *name* of an unknown plant; and, until this has been made out, the previous determination of its class and order gives no indication of its general structure and properties (not even making it apparent whether it is an Endogen or an Exogen, a Dicotyledon or a Monocotyledon), since under the same head are grouped genera of the most opposite character. It may be said that it serves as a sort of Alphabetical index to a book, enabling the reader to turn to any part of it he wishes, by looking out the subject in the order of its first letters, but giving no idea whatever of the general scope of the book, nor of the mode in which its subjects are arranged.

481. The Linnæan System is liable to many imperfections and difficulties in its application, even in the limited circle of British Plants; for example, the number of pistils is liable to be altered in any species by the more or less complete adhesion of the carpels; and that of the stamens may also vary in the different species of the same genus, and even among the different individuals of the same species, or even (in some instances) among the different flowers of the same stem. The adoption of characters thus liable to vary cannot, therefore, but sometimes lead to confusion. For instance, of the genus Polygonum, of which the several British species are known by the names of Bistort, Buckwheat, Persicaria, &c., one has always, and two others have occasionally, eight stamens; whilst in the rest the number varies from five to ten. As eight seems to be the most regular number, the genus is placed in the class Octandria: and although its styles are sometimes only two in number, it is placed in the order Trigynia, because they are more commonly triple. Now if a

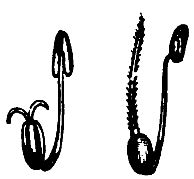
student meet with a specimen which has five, six, or ten stamens, he will vainly search for its character among the genera of the Linnæan class to which it would seem to belong; and unless he happen to consult a book which makes special mention of the genus in these several classes, he will be altogether at fault. Suppose that some more knowing Botanist tells him that his plant is a Polygonum, he will again turn to his book, wondering how he could have overlooked it; but he will find the genus in the class Octandria, in spite of the different number of stamens in the specimen before him: and he will then learn that it is placed in the genus Polygonum on account of its strong general resemblance to other Polygonums, although differing from them in characters which are ordinarily considered as sufficient to establish classes and orders. Again, the greater part of the species of the genus *Rhamnus* (Buckthorn) possess both stamens and pistils in the same flower; but the species most commonly known in this country on account of its purgative properties is Diœcious, the staminiferous flowers being on one plant, and the pistilliferous on another (§. 435). The student who meets with it, therefore, would seek for it in the class Diœcia, where he would be disappointed as before; since, as in most species the flowers are complete, it is placed in the class and order to which the number of its stamens and pistils would refer it.

482. Such exceptional cases occur much more frequently than is commonly supposed. It has been proved that, in fourteen divisions of the Linnæan system, including 173 British genera, there are no less than 43 exceptions,—one-quarter of the whole; and that out of 274 genera of North America, belonging to eighteen Linnæan sections, there are 78 exceptions,—rather more than a quarter. These facts are important, both as preparing the student to meet with such difficulties, even in the study of the Linnæan system, which is generally considered so easy of application; and also as showing the imperfection of the system itself, which is of no value whatever, beyond the temporary purpose of facilitating the early studies of the Botanical Student. In well-arranged descriptions of British Plants (such as Hooker's British Flora, which may be strongly recommended for this purpose) the most perplexing of these cases are noticed, in such a

manner as to prevent the loss of time and labour, in vain attempts at discovering genera in wrong classes, or species in wrong genera.

483. Entertaining, as the writer does, from some experience in the matter, the foregoing opinion of the advantages of the Linnæan System for a beginner, it is desirable here to give an outline of the principles upon which its divisions are founded, which may serve as an introduction to the regular systematic treatises on the subject. The Phanerogamia or Flowering Plants are distributed under twenty-three Classes, all of which are characterised either by the *number* or particular *arrangement* of the stamens. In the first twelve of these, *number* alone is regarded. Their names are formed by the combination of the Greek numeral expressing the required number, with the termination *andria*, which has reference to the supposed *male* office of the stamens in the process of fertilization. These classes, therefore, stand simply as shown in the following figures :—

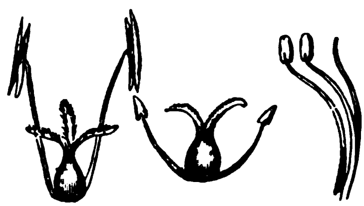
Fig. 104.



Digynia. Monogynia.

Class I.—Monandria. One stamen. *Orders* — Monogynia and Digynia.

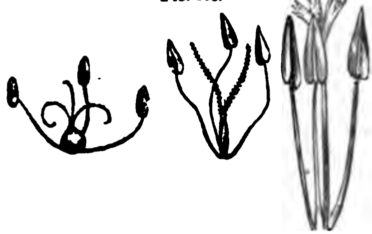
Fig. 105.



Trigynia. Digynia. Monogynia.

Class II.—Diandria. Two stamens. *Orders*—Monogynia, Digynia, and Trigynia.

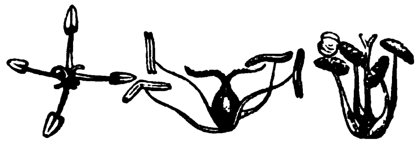
Fig. 106.



Trigynia. Digynia. Monogynia.

Class III.—Triandria. Three stamens. *Orders*—Monogynia, Digynia, and Trigynia.

FIG. 107.



Tetragynia. Digynia. Monogynia.

CLASS IV.—TETRANDRIA. Four stamens. *Orders*—Monogynia, Digynia, and Tetragynia.

FIG. 108.

Trigynia. Digynia. Monogynia. Pentagynia. Tetragynia.

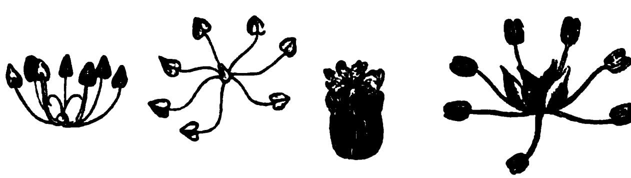
CLASS V.—PENTANDRIA. Five stamens. *Orders*—Monogynia, Digynia, Trigynia, Tetragynia, Pentagynia, and Polygynia.

FIG. 109.

Trigynia. Digynia.

CLASS VI.—HEXANDRIA. Six stamens. *Orders*—Monogynia, Digynia, Trigynia, and Polygynia.

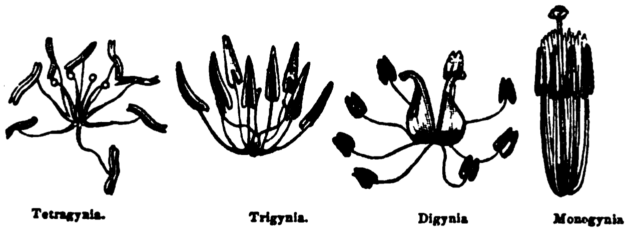
FIG. 110.



Digynia. Monogynia. Heptagynia. Tetragynia.

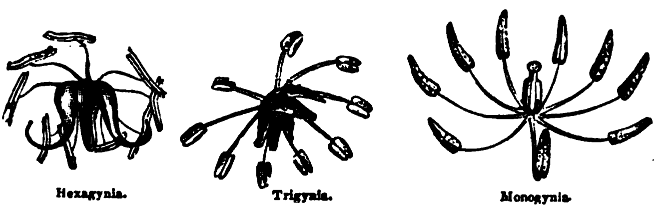
CLASS VII.—HEPTANDRIA. Seven stamens. *Orders*—Monogynia, Digynia, Tetragynia and Heptagynia.

Fig. 111.



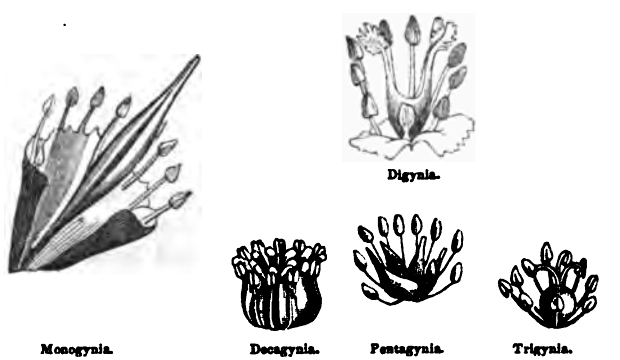
Class VIII.—Octandria. Eight stamens. *Orders*—Monogynia, Digynia, Trigynia, and Tetragynia.

Fig. 112.



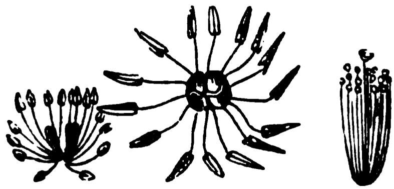
Class IX.—Enneandria. Nine stamens. *Orders*—Monogynia, Trigynia, and Hexagynia.

Fig. 113.

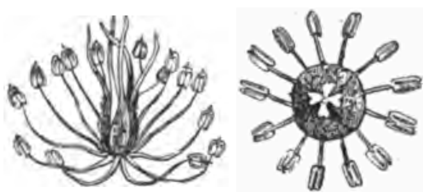


Class X.—Decandria. Ten stamens. *Orders*—Monogynia, Digynia, Trigynia, Pentagynia, and Decagynia.

FIG. 114.



Trigynia. Digynia. Monogynia.



Pentagynia. Tetragynia.

CLASS XI.—DODECANDRIA. Twelve to nineteen stamens. *Orders*—Monogynia, Digynia, Trigynia, Tetragynia, Pentagynia, Hexagynia, and Dodecagynia.

FIG. 115.

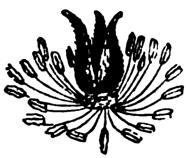
Polygynia. Di-Pentagynia. Monogynia.

CLASS XII.—ICOSANDRIA. Twenty or more stamens inserted into the calyx. *Orders*—Monogynia, Di-Pentagynia, and Polygynia.

To the last mentioned class, however, another character belongs; for in the next class, POLYANDRIA, the number of stamens is also twenty or more. They are distinguished by the mode of insertion of the stamens; these appearing to arise from the calyx in the former, and from the disk or receptacle in the latter. This distinction, which will be hereafter shown to be important in the Natural System, will be at once understood by comparing a true Rose, Plum, Cherry, or Pear blossom, with a Christmas Rose,

an Anemone, or a Pæony; when the calyx and corolla of the former are pulled off, they carry the stamens with them; but they may be entirely removed from the latter, leaving the stamens attached to the disk. These two classes will, therefore, stand as follows:—

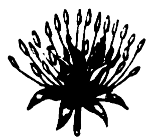
FIG. 116.



Di-Trigynia.

Monogynia.

Polygynia.

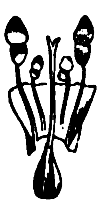


Pentagynia.

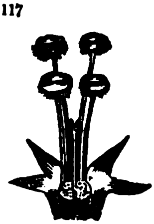
CLASS XIII.—POLYANDRIA. Twenty stamens or more, inserted into the receptacle. *Orders*—Monogynia, Digynia, Trigynia, Tetragynia, Pentagynia, and Polygynia.

The next two classes are characterised by peculiarities in the proportional length of the stamens, as well as in their number. Those which are *longer* than the rest are said to be *in power;* and the termination *dynamia* is applied to the number of these, in order to designate their peculiarity.

FIG. 117



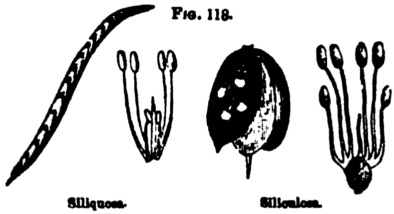
Angiospermia.



Gymnospermia.

CLASS XIV.—DIDYNAMIA. Four stamens, two longer than the others. *Orders*—Gymnospermia and Angiospermia.

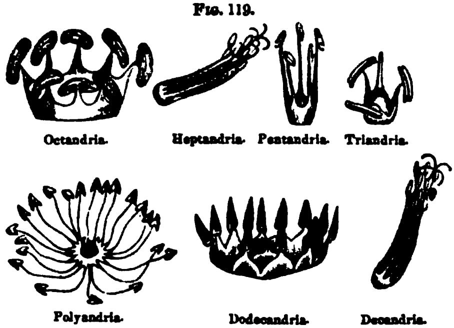
FIG. 118.



CLASS XV.—TETRADYNAMIA. Six stamens, four longer than the others. *Orders*—Siliquosa, Siliculosa.

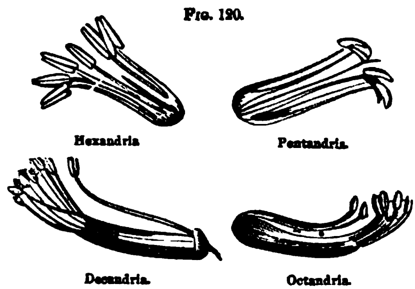
The three following classes are characterised by the more or less complete union of the filaments of the stamens into bundles, or *brotherhoods;* on account of which the termination *adelphia* is applied to the number of such bundles.

FIG. 119.



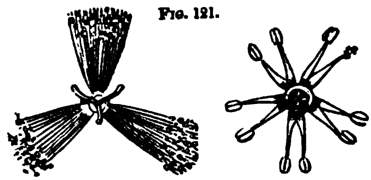
CLASS XVI.—MONADELPHIA. Stamens united into a single bundle, forming a tube which surrounds the style. *Orders*—Triandria, Pentandria, Hexandria, Heptandria, Octandria, Decandria, Dodecandria, and Polyandria.

FIG. 120.



CLASS XVII.—DIADELPHIA. Stamens united into two bundles. *Orders*—Pentandria, Hexandria, Octandria and Decandria.

Fig. 121.

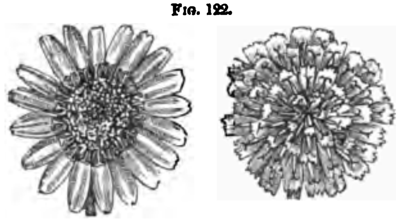


Polyandria. Decandria.

Class XVIII.—Polyadelphia. Stamens united into several bundles. *Orders*—Decandria, and Polyandria.

In the next class, it is the anthers which form the tube; and the name applied to it signifies a *growth together*. In the succeeding class, the stamens and the pistil grow together; and the name *gyn-andria* refers to this union of the male organs with the female, the latter being designated by the first syllable, which will presently be seen to be much employed in the description of the orders.

Fig. 122.



Superflua. Æqualis.

Class XIX.—Syngenesia. Stamens united by their anthers into a tube. *Orders*—Æqualis, Superflua, Frustranea, and Necessaria.

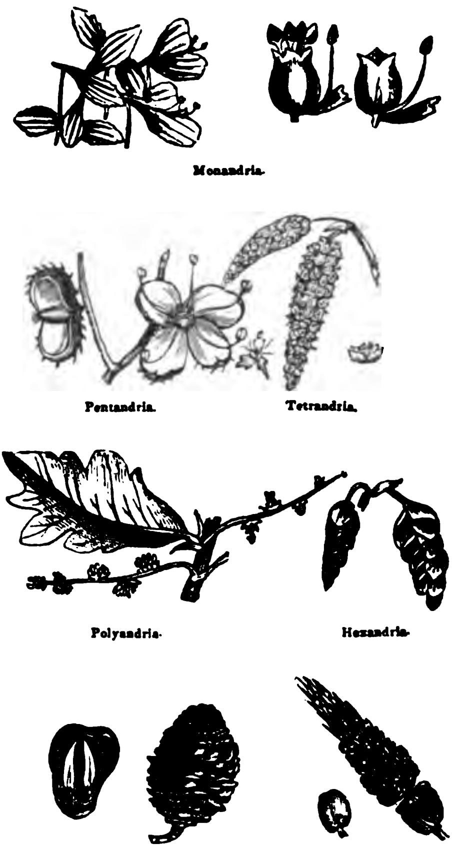
Fig. 123.

Hexandria. Diandria. Monandria.

Class XX.—Gynandria. Stamens and pistils grown together. *Orders*—Monandria, Diandria, and Hexandria.

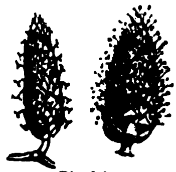
The three remaining classes are characterised by the separation of the staminiferous and pistilliferous flowers; the import of the names of the first two has been already explained (§. 435).

Fig. 194.

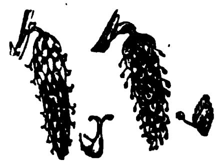


Class XXI.—Monœcia. Stamens and pistils in separate flowers, but both growing on the same plant. *Orders*—Monandria, Diandria, Triandria, Tetrandria, Pentandria, Hexandria, Octandria, Icosandria, Polyandria, and Monadelphia.

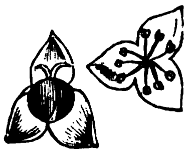
FIG. 125.



Diandria.



Monandria.



Enneandria.

Octandria.

Monadelphia.

CLASS XXII.—DIŒCIA. Stamens and pistils not only on two flowers, but these flowers on two different plants. *Orders*—Monandria, Diandria, Triandria, Tetrandria, Pentandria, Hexandria, Octandria, Enneandria, Decandria, Dodecandria, Icosandria, Polyandria, and Monadelphia.

FIG. 126.

Diœcia.

CLASS XXIII.—POLYGAMIA. Stamens and pistils separated in some flowers, united in others, either on the same plant or on two or three different ones. *Orders*—Monœcia and Diœcia.

Monœcia.

484. The Orders, or subdivisions of the classes, are generally founded upon the number of the styles, or (if these be not present) of the stigmas; or upon certain peculiarities of the seed-vessel. In the first thirteen classes, the number alone is regarded; and the orders are designated, as before, by the Greek numerals, with the termination *gynia*, which refers to the supposed female character of the pistil.

Order	1.	*Monogynia*,	One Style
	2.	*Digynia*,	Two Styles
	3.	*Trigynia*,	Three Styles
	4.	*Tetragynia*,	Four Styles
	5.	*Pentagynia*,	Five Styles
	6.	*Hexagynia*,	Six Styles
	7.	*Heptagynia*,	Seven Styles
	8.	*Octogynia*,	Eight Styles
	9.	*Enneagynia*,	Nine Styles
	10.	*Decagynia*,	Ten Styles
	11.	*Dodecagynia*,	Twelve Styles
	12.	*Polygynia*,	More than Twelve Styles.

It will be evident, from the description of the structure of the pistil formerly given (§. 434), that the number of styles affords no indication of the character of the ovarium. Thus, the ovarium may be formed of many carpels, the divisions between which remain as distinct partitions, whilst the styles and stigmata of all these may have coalesced into one pillar; so that we may have a single style with a many-celled seed-vessel. On the other hand, the walls of the carpels may form but incomplete partitions, so that the cavity of the ovarium is undivided (Fig. 50); whilst the styles and stigmata may be numerous. It will hereafter be shown that the structure of the ovarium itself is a much less variable character than the number of styles, which is liable to alteration in many species (like that of the stamens) through the adhesion or the non-development of some of them. In the class DIDYNAMIA, the characters of the orders are drawn from the structure of the seed-vessel. The first, *Gymnospermia*, or naked-seeded, includes those in which the ovary has four carpels, each enclosing a single seed; and this, when mature, fills up the cavity in such a manner, that the wall of the seed-vessel appears like an outer coat to the seeds, which thus do not seem to have any

other envelope. We shall hereafter find that the only *true* naked-seeded plants are the Coniferæ or Pine tribe, and its allies, in which the seeds never are enclosed in a seed-vessel. The second Order, *Angiospermia*, includes those Didynamia which have a distinct seed-capsule, usually two-celled, each cavity containing many seeds. In the next class, TETRADYNAMIA, there are also two orders, distinguished by the form of their pod-like seed-vessel;—the first, *Siliquosæ*, having a long-pod;—the second, *Siliculosæ*, a short one. The Orders of the classes, MONADELPHIA, DIADELPHIA, POLYADELPHIA, depend upon the number of their stamens; and they have the same names as the first thirteen classes,—the number of stamens, however, being never less than five. The subdivision of the class SYNGENESIA (as now understood) is rather complex; and, as it is nearly the same in the Natural System, it will be better explained under the Order Compositæ. The orders of the classes, GYNANDRIA, MONŒCIA, and DIŒCIA, are distinguished by the number of stamens, and are consequently *Monandria*, *Pentandria*, &c. Those of the class POLYGAMIA are the *Monœcia*, in which the same plant bears staminiferous, pistilline, and complete flowers; and the *Diœcia*, in which these occur on different individuals.

485. There are many of these orders which form groups truly natural; that is, which consist of genera having a large number of points of agreement with each other, independently of the characters on which the subdivision is founded. For example, one portion of the class PENTANDRIA, order *Digynia*, corresponds with the Natural Order *Umbelliferæ* (including the Parsley, Carrot, Hemlock, Parsnep, &c.); the Class TRIANDRIA, order *Digynia*, very nearly corresponds with the natural group of Grasses, all these having three stamens and two styles, which combination is not found in any other plants. The DIDYNAMIA *Gymnospermia*, again, are the same with the Natural Order *Labiatæ*, to which belong the various kinds of Mint, Thyme, Dead Nettle, &c.; and the class TETRADYNAMIA corresponds with the natural Order *Cruciferæ*, to which belong the Mustard, Cress, Cabbage, Turnip, Stock, Wall-flower, &c. From the predominance of the number *three* and its multiples in the parts

of the flower of Endogens, we find most of this group included in the classes Triandria, Hexandria, and Enneandria; whilst the prevalence of the numbers four and five among Exogens, causes the classes Tetrandria and Pentandria, Octandria and Decandria, with Icosandria and Polyandria, to contain a very large proportion of that division. But the Linnæan system often brings together Exogens and Endogens into close contact; besides breaking up the natural alliances of each, so as to scatter widely apart the members of groups nearly united. Examples of this will be hereafter given.

486. The Natural System, on the other hand, aims to present an harmonious and consistent view of the Vegetable Kingdom, by associating into Orders those genera which agree in the most numerous and important characters, and which differ from others in the same. A table of the characters of these Orders would therefore resemble the Table of Contents of a well-arranged book; giving at one glance to a person at all acquainted with the subject, an idea of the mode in which it is treated by the author, and of the relations which the several divisions of it had in his mind; and enabling a person who is entering upon the study of it, to do so with the knowledge that he is not gleaning at random, as if he were reading through a Dictionary, but that every acquisition he makes of an individual part is something toward an acquaintance with the plan of the whole. One more illustration may set this matter in a still clearer light. The reader may be requested to consider this series of Treatises as completed according to the original plan; and as consisting of a number of Volumes, each devoted to some particular Science, but all having a certain degree of connexion with each other. Each Volume consists of a series of Chapters, in which the subdivisions of these Sciences are respectively treated of, and among which there is a still closer degree of connexion. Every chapter, again, is made up of a number of paragraphs, each intended to contain one or more important facts, the knowledge of which is in itself useful, but which can only be fully understood when read continuously with the preceding and following paragraphs. We shall further suppose that the subject of every paragraph

could be concisely expressed by a single word. Now we will imagine these paragraphs, all printed on separate slips of paper, with their appropriate titles, to be given to a Man of Science, with a request that he would arrange them for publication. His first idea might, perhaps, be, to place them in alphabetical order, so as to form a kind of Dictionary; this being the most easy method of fulfilling his task, and also having the advantage, when complete, of admitting very easy reference to any required subject. But what idea would the reader of such a volume gain, of the plan which the original Author had in his mind? Or what connected and harmonious scheme of knowledge could he frame from them, unless he digested and arranged them in his own mind, in the manner in which we shall suppose our Man of Science to proceed to do? He might commence in two ways;—either by separating the whole into heaps, according to the subjects to which they respectively refer, *e. g.* Mechanics, Chemistry, Geology, Botany, Zoology, &c., and then arranging these singly;—or by endeavouring to join the separate paragraphs together, according to their obvious connection. He will probably find a combination of these two methods the most advantageous; and by a careful examination of each single paragraph, in its relations to the whole, he may at last succeed in producing a series of connected Treatises, methodically arranged according to their respective subjects, and regularly divided into chapters, very nearly, or even exactly, upon the plan of the original Author. Now the Alphabetical arrangement would bear a close parallel with the Linnæan system of Botanical classification; whilst the latter distribution,—the one evidently most calculated to convey to the learner a *connected* rather than a *desultory* knowledge of the several objects of his pursuit, may not unaptly represent the Natural System.

487. It is by seeking for the latter only, that any of those general principles can ever be attained, which give their chief value to the facts of Science, and which lead us higher and higher in the contemplation of that Almighty Power and Boundless Wisdom by which the Universe was framed; for *the* Natural System would be but a Table of Contents of the Vegetable Kingdom, arranged on the plan of its Divine Author. In order

to attain it, the Botanist requires to become acquainted, not only with all the tribes of Vegetables at present existing on the surface of the globe, but with the forms and characters of those which have once existed; since—it cannot be doubted—all these constituted parts of the one general scheme, without the knowledge of which it would be impossible to reconstruct it. Now it is well known to the Botanist, that a very large number of the species of Plants with which he is somewhat acquainted, have been so imperfectly examined and described, that their true place in the system cannot be determined; and there is good reason to believe that there are many more of which he is totally ignorant. Here, therefore, are abundant causes for the imperfection of any natural system which can be at present framed; and should these ever be removed by long-continued labour and research, there will yet remain the other causes, resulting from the impossibility of becoming fully acquainted with the characters of the races, which have existed in former periods of the earth's history, and which have been swept completely from its face. Of these, some remains are occasionally discovered, sufficiently perfect to excite the liveliest interest and curiosity, by showing that races once flourished, which fill up many of the wide gaps existing between those with whose characters we are now familiar, and which, if we knew more of them, would explain many things that are at present most perplexing.

488. Some of the strongest upholders of the Linnæan system are influenced by their veneration for its author; whose fame, however, will rest on a foundation much more durable than this. It is not generally known that the advantages of the Natural method have never been more highly appreciated, than they were by Linnæus himself. When he framed an Artificial system for the convenient arrangement of plants, it was with the very purpose for which the temporary employment of it has been here recommended,—namely, to facilitate that acquaintance with the Vegetable Kingdom, which must be gained before a Natural method can be framed. Linnæus himself gave a sketch of the Natural System, explaining the principles upon which it might be expected to rest; and he pronounced the investigation of the

natural affinities to be the great object of his studies, and the most important part of the science. He considered the Artificial system as a temporary expedient, which, however necessary at that day, would inevitably give place to the system of nature, so soon as its fundamental principles should be discovered. The elucidation of the latter, he said, is the first and ultimate aim of Botanists; to this end the labour of the greatest Botanists should be diligently directed; and the merest fragments of this system should be carefully studied. Though not then fully discovered, he spoke of the pursuit of it as held in high estimation by the wisest Botanists, and as being thought of little consequence only by the less learned. "For a long time," he adds, "I have laboured to establish it; I have made many discoveries, but have not been able to perfect it; yet while I live, I shall continue to labour for its completion. In the mean time, I have published what I have been able to discover; and whosoever shall resolve the few plants which still remain, shall be my Magnus Apollo. Those are the greatest Botanists, who are able to correct, augment, and perfect this method; which those who are unqualified should not attempt." Those therefore, who, priding themselves upon their being disciples of Linnæus, continue to employ his temporary and artificial system of classification, to the exclusion of one founded upon Natural principles, imagining that they are upheld by his authority, quite mistake the views of their great master, and sadly misrepresent his opinions.

489. The knowledge of the Vegetable Kingdom obtained by Linnæus, however, was far too small in amount, to enable him to frame a Natural System upon sound principles. The number of species known to him was probably not an eighth part of those with which Botanists are now acquainted; and no arrangement, therefore, could be formed, which was not marked by many wide and unsightly gaps. Further, so little was at that time known of the internal arrangement of the organs of plants, that even the distinction between the two principal forms of structure in the stem,—evident and well-marked as it now appears,—was not then understood. Nevertheless, with that sagacity which so remarkably characterised him, Linnæus succeeded in grouping together genera into orders, which are even

now regarded as, for the most part, very natural assemblages; that is, as containing plants really allied to each other in their most important characters, and differing from those of other orders in the same. But of the best mode of arranging these orders he was necessarily ignorant, since the *most* important characters were not then understood. The great progress which has been made since his time, in the Structural and Physiological departments of Botanical Science, has done much to place Classification on a more certain basis; yet there is still much wanting, before Botanists shall be generally agreed on the principles which shall regulate the division and subdivision of the Vegetable Kingdom. In the following outline, the object is less to give a bare sketch of the entire system, than to offer such a view of it, as may serve to show its nature. It is intended to describe most fully those Orders to which the greatest number of British Plants belong; and to state the relations which the species of most importance to man, whether as furnishing articles of food, valuable medicines, or materials for his various arts, bear to these. In so doing, it has been deemed advisable to adopt the Classification of De Candolle, being the one which is most in use at the present time; and the principles upon which it is founded will, therefore, now be explained.

490. It may be remarked, however, in the first place, as a principle common to all Systems of Classification which profess to be Natural, that the different values which are attached to the various characters furnished by the several organs of plants, should be estimated by the degree in which they respectively indicate important similarities or differences of *general* conformation. It often happens that attention to one or two characters may afford a considerable amount of knowledge of the whole; because those characters are found to be inseparably connected with others. An instance of this has been already given, in regard to the primary division between Exogens and Endogens (§. 478); and it may be useful to illustrate it further by reference to the Animal kingdom. If, for example, we meet with an Animal covered with feathers, we at once know a great deal of its internal structure and economy. It is a *Vertebrated* animal, possessing a jointed back-bone and complete internal skeleton;

it has all five senses; its blood is red; it breathes air; its temperature is high; its young are produced from eggs; it walks upon two legs; &c. &c. Here we are at once informed that this unknown animal possesses all the characters peculiar to the class of Birds; since no other animals than Birds possess a covering of feathers, which is inseparably connected with the whole plan of their structure and economy. In the same manner, the classification of the Mammalia (Quadrupeds) according to their teeth, proposed by Linnæus, proves to be a very natural one, although founded upon a single set of characters; because the form and number of the teeth vary with the nature of the food on which the animal is intended to live; and to make use of this, a certain form of digestive apparatus is adapted; as well as a certain kind of general structure, furnishing the instruments by which the food is obtained: so that these may be known to a great extent from the inspection of the teeth alone. In like manner the Botanist, whilst founding his arrangement upon the whole group of characters which each Plant exhibits, endeavours to select those, as marks for distinguishing the several divisions, which are at once easily recognised, and which serve as the best key (so to speak) to those which are seated within. Such characters are Natural, then, in proportion as they indicate *general* conformity or difference of structure; thus, the distribution of the veins of the leaves,—a character easily recognised,—will in general serve to distinguish Exogens and Dicotyledons from Endogens and Monocotyledons; and it is therefore a very natural character, serving as a key to all those which are indicated by these terms. On the other hand, the number of stamens and pistils in a flower is a purely artificial character, since it gives no further certain information of the general structure of the plant.

491. Another general principle of Natural classification must next be pointed out. When a number of Plants or Animals are associated, on account of their general resemblance to each other, into a Natural group, it will be found that the characters in which they agree are presented by some members of the group much more prominently than by others; and that in some they are occasionally so much wanting, that these can scarcely be

regarded as connected with the rest; yet they would not seem to be more easily included in any other groups. Now those members of a natural group which most strikingly present a union of all the characters by which it is distinguished, are spoken of as its *types;* and those in which these characters are less obvious are termed *aberrant* members of the group. It is by these, in fact, that natural groups are connected with one another; for it will generally be found that in the aberrant members of one group, its characters become (as it were) gradually shaded off, until they almost blend with those of the next. To revert to an illustration formerly (§. 18) employed;—where the countries occupied by two nations are not separated by any marked natural boundary (as a broad river or high chain of mountains), the peculiar characters of these nations, which may be regarded as most strongly exhibited in their respective chief towns, become gradually blended towards the border where they meet; so that the transition from one to the other is by no means so abrupt, as if the traveller were conveyed at once from the metropolis of each to that of the other. Every natural group, then, may be regarded as a sphere, surrounded by other spheres—each representing another group,—which touch it at certain points; the *type* of each will occupy its centre; and the *aberrant* members will be disposed in various positions around it, in proportion as they lose *its* peculiar characters and approach other groups. For example, the group of Lizards is intermediate between that of Serpents and that of Tortoises. There are some Lizards in which the body and tail are greatly lengthened, whilst the legs are shortened, so that the form of the Snake is approached; and in the common Slow-worm or Blind-worm of this country, the external form is completely that of a Snake, whilst beneath the skin two pairs of small though perfectly-formed legs may be found on careful examination. This, then, is an *aberrant* form, situated just on the border of both groups, and scarcely having a certain claim to a place in either. On the other side, the Lizards are connected with the Tortoises by an American species commonly known under the name of the Alligator-Tortoise, or Snapping-Turtle, which may be considered as a Tortoise with a long Lizard-like neck, legs, and tail, or as a Lizard with a Turtle-shell on its back.

The Lizards are connected, again, with Birds (to which they would not seem to have the slightest possible relation), by means of a very curious animal not now existing, which had the general structure of the Lizards; but which had the fore-legs converted into wings like those of a Bird; and which seems to have been covered with something intermediate between scales and feathers. Many similar instances will present themselves in the study of the Vegetable Kingdom.

492. Hence when it is stated that a Plant or Animal belongs to a particular group, it is by no means necessarily implied that it possesses *all* the characters which are considered as marking that group. Thus,—to revert to an instance just now employed in illustration,—the structure of the feathers, which are generally so characteristic of the class of Birds, is greatly modified in some of the species which approach nearest to other groups; in the Emu, for example (one of the Ostrich tribe), the feathers are little else than stiff branching hairs; and in the Penguin, those covering the fin-like wings resemble scales. So, again, in the first Natural group of plants which we shall consider,—the *Ranunculus* or Crowfoot tribe,—there are some species which have the parts of the flower arranged in *threes*, as in Endogens; yet they are not really such, for their stems are Exogenous, the veining of their leaves is netted, and their embryo is dicotyledonous. Again the common *Arum maculatum* (Cuckow-pint or Wake-robin) has reticulated leaves; but it is not an Exogen, because its stem is Endogenous, and its embryo monocotyledonous. And the Pond-weed (*Potamogeton*) has the parts of its flowers arranged in fours; yet it does not belong to Exogens, since its leaves are parallel-veined and its embryo is monocotyledonous.

493. In considering the value of the several characters afforded by the varieties in the structure of Plants, it will be convenient to follow the same order as that which has been adopted in describing that structure. The Elementary Tissues do not afford any means of distinction, except in regard to the primary divisions,—the presence of Spiral Vessels being on the whole characteristic of Flowering Plants (which have been hence termed *Vasculares*); and their absence being nearly constant in

Cryptogamia (which have been hence termed *Cellulares*). There are some of the inferior Phanerogamia, however, in which no spiral vessels can be detected; and in the Ferns, which stand at the head of the Cryptogamia, modifications of them may be found. However, if on examining any portion of the fabric of an unknown plant, spiral vessels were distinctly seen, this might be regarded as sufficiently indicating that the specimen belonged to the higher of these two groups. The peculiarity of the woody fibre in the *Coniferæ* and allied orders (§. 78), together with the absence of the dotted-ducts or special sap vessels, is characteristic of that portion of the Phanerogamic division; but excepting in this instance, no use can be made of the varieties of the elementary tissues, in defining the subdivisions of the classes of Plants.

494. The structure and mode of increase of the Stem afford, as already stated, the means of establishing the soundest division of the Phanerogamia: and the two groups of Exogens and Endogens are universally recognised as natural classes. Between these, however, there are several connecting links,—some Exogens exhibiting in their stem no separation into annual layers,—and some Endogens, presenting an approach to the Exogenous division of the kingdom. One small order (*Calycantheæ*) is known by the presence of four incomplete centres of vegetation surrounding the principal one; and the Passion-flower tribe are remarkable for having the stem almost cut into four quarters: whilst a square stem is universal in the Dead-Nettle tribe. In some orders, such as the *Cacteæ* (Prickly-Pear tribe) and *Euphorbiaceæ* (Spurge Tribe), the quantity of cellular tissue usually so much predominates that the stems are soft and succulent; but this is not always the case, some genera having stems of the ordinary character. No very positive characters can in general, therefore, be drawn from the structure of the stem, in dividing the classes into sub-classes and orders. Nor do the Roots afford any better guide; since the modifications of form of which they are susceptible are very few, and they are by no means constant in particular groups. As a general rule, however, it may be observed that neither bulb nor rhizoma (§. 149, 150) are found

in Exogens, and that they are confined to a few orders among Endogens.

495. The Leaves are subject to considerable modifications, both in position, form, and structure, which are very useful in classification. The general differences among the leaves of Exogens, Endogens, and Acrogens, have already been several times adverted to. The relative position of the leaves, as whether alternate, opposite, or verticillate, is often a very important character; but in regard to this, as well as to other characters, it often happens that it is of much greater value in some orders than it is in others. Thus in *Lamiaceæ* (Dead-Nettles) they are uniformly opposite: so that no plant can belong to the order, in which they are alternate or verticillate. In *Urticaceæ* (the Nettle tribe), on the other hand, they are constantly alternate; so that no opposite-leaved plant can belong to the order. In this manner the common Dead-Nettles and Stinging-Nettles may be at once known from each other. But in many others, one arrangement is prevalent, and yet the other sometimes occurs. The degree of division of the leaves, again, is subject to considerable uncertainty in many orders, from causes formerly adverted to (§. 234—9); yet in others a constant form is maintained; thus, leaves with teeth or jagged edges are never found in the order *Cinchonaceæ* (from which the Peruvian Bark is supplied), and they are very rare in Endogens. The particular characters afforded by the veining of leaves are much more constant, as formerly shown (§. 235), than those derived from their form; and it is probable that, as they have only been recently attended to, much assistance will be obtained in classification from an increased knowledge of them. A character which would not at first sight appear of much importance, is afforded by the presence or absence of those little dots in the leaves, which are reservoirs of oily secretions; yet these, being connected as it would seem with some important differences in the general economy, are extremely characteristic of certain natural orders, such as *Myrtaceæ* (the Myrtle tribe), and *Aurantiaceæ* (the Orange tribe), serving to distinguish all their members from those of other orders nearly allied to them. In other orders, however, there are some

genera with, and others without these pellucid dots. The clear or milky character of the juices of the leaves and stalks, indicating as it does the absence or presence of certain secretions which are characteristic of particular orders, will often prove of much use in distinguishing their members. At the base of the leaf-stalks are often found little leafy appendages (which are in fact leaves, in an imperfect state of development), termed Stipules; the presence or absence of these frequently enables the Botanist to distinguish the plants of two allied orders, of which one possesses them, whilst the other does not; and certain peculiarities in them, which will be hereafter noticed, are occasionally very characteristic of particular groups.

496. Passing on to the Flowers, we first have to notice the characters afforded by the bracts; these are seldom of any use in distinguishing orders, on account of their constant variation within the limits of each; but they are often valuable in separating genera and species. The calyx is used in a variety of ways to distinguish orders; but the characters it affords are far from being of equal or uniform importance throughout. The number of sepals is sometimes a very useful and constant mark of a particular order; thus, in Cruciferæ, the Cabbage and Turnip tribe, they are always four, and in Papaveraceæ, the Poppy tribe, always two: but in many orders it is extremely variable. The equal or differing size of the sepals is another character of great importance in some cases, but not to be regarded in others. Again, the union of the sepals by the adhesion of their edges, is a character to which great value may usually be attached; when this adhesion unites all the sepals, the calyx is commonly said to be *monosepalous* (single-sepalled); but the term *gamosepalous*, expressing the union or adhesion of the sepals, is to be preferred. A still more important character is the degree of adhesion of the calyx to the organs it includes. Where it arises immediately from the disk or expanded top of the flower-stalk, and where the corolla, stamens, and pistil are quite distinct from it, arising by themselves from the disk (as in Fig. 127), the calyx is said to be *inferior* to the ovary, or non-adherent to it. But where the calyx seems to spring from the top of the ovary or seed-vessel,

instead of beneath it (as in Fig. 129), it is called *superior;* this conformation is due to the adhesion of the calyx to the wall of the ovarium, so that it forms a tube completely enclosing it, as in the Rose, Apple, &c. In some plants the calyx is altogether absent; and then the general rule is that the corolla is likewise deficient. Such plants are said to be *Achlamydeous*, the essential parts of their flowers being destitute of envelope. In the Compositæ, however, which possess a corolla, the calyx is present in an undeveloped form, constituting the *down* or *pappus*, which surrounds the bottom of the corolla, and is attached to the top of the seed-vessel, as in the Dandelion.

497. In regard to the number and regularity of the parts of the corolla, nearly the same may be said as of the calyx. These characters are valuable in some instances and not in others. The separation or adhesion of the petals, constituting what is commonly known as the polypetalous or monopetalous corolla, is often a character of first-rate importance, as will presently appear. Still, from the cause formerly mentioned, (§. 456) it is liable to some uncertainty, and must not, therefore, be trusted too implicitly. Sometimes no corolla is to be found, the calyx still being present; and the plant is then said to be *apetalous* (destitute of petals), or *Monochlamydeous* (having but one envelope). This is a character, however, on which great reliance cannot be placed; since *apetalous* genera frequently present themselves, in orders which usually possess complete flowers,—an occurrence which is less common amongst monopetalous Exogens, than among those which have separate petals, so that the character is of more value in the former than in the latter.

498. When our attention is directed to the more essential parts of the flowering system,—the stamens and pistil,—we meet with some characters on which more constant reliance can be placed; but these are not among the most obvious, such as the inexperienced Botanist would first attend to. For example, the number of stamens is a character to which little importance can be attached; since this is liable to vary extremely among the genera of almost every order,—in many cases among the species of the same genus,—not unfrequently, among individuals

of the same species,—and even in different flowers on the same plant. Yet there are particular orders, in which the number of stamens is very constant throughout, and is very characteristic of them. The most important characters afforded by the stamens, are drawn from their mode of origin from the lower part of the flower. They may arise, like the sepals and petals, from the disk, beneath the ovary; in this case they are said to be *hypogynous* (this term designating their origin from *beneath* the *female* part of the flower). A sectional view of a flower constructed upon this plan is shown in Fig. 127; the sepals of the calyx, the petals of the corolla, the stamens, and the pistil, are there shown to be all separately implanted on the disk. But it may happen that the sepals and stamens arise together, (these parts being opposite in a regular flower, whilst the petals alternate with them so as not to prevent their adhesion, §. 463), and that they adhere for a part of their length, so that the stamens appear to arise from the calyx, and come away with it when it is detached; in this case, or when they adhere in a similar manner to the petals, they are said to be *perigynous*, having their origin *around* the female organ. A plan of such a structure is shown in Fig. 128. Lastly, when the calyx embraces the ovarium, it also closely envelops the stamens, which are not freed from it except at the top of the seed-vessel; in this case, the stamens, appearing to arise from the top of the ovarium, are said to be *epigynous*, being seated

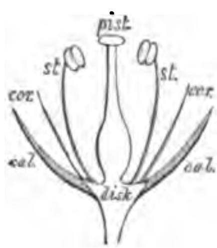


FIG. 127.

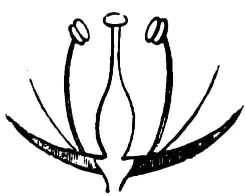


FIG. 128.

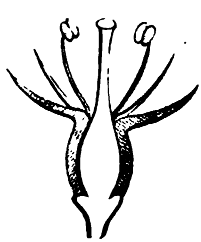


FIG. 129.

upon the female organ. This mode of conformation is illustrated by Fig. 129, which also explains what was meant by a *superior calyx* (§. 496). Peculiarities in the mode in which the anthers open to disperse the pollen are sometimes characteristic of particular orders; thus the *Berberry* and *Laurel* tribes have anthers bursting by valves; and the *Heaths* have anthers opening by pores (§. 433). But such peculiarities are found in other genera, amongst orders which do not possess them; and they must not, therefore, be implicitly relied on.

499. Of all natural characters, those furnished by the structure of the central parts of the flower are perhaps subject to the fewest exceptions; yet these are not such as are the most evident to the ordinary observer. On the number of styles, as already stated, little reliance can be placed for the establishment of important distinctions; but as it is less liable to vary than is that of the stamens, it may often be useful in the separation of genera. A much more decisive character is afforded by the degree of adhesion among the carpels; when they remain distinct from each other, the ovary is said to be *apocarpous* (carpels apart); and when they are compactly united, it is termed *syncarpous* (carpels together). There are few natural orders in which one or other of these conditions does not prevail, to the entire exclusion of the other; so that plants which bear a strong resemblance in general aspect, but differ in this, may be at once referred to their proper groups. The *position* of the ovary in respect to the calyx has been already adverted to; this character is generally expressed by the terms *inferior* or *superior* ovary. The presence or absence of partitions in the ovaries, is a very important distinction. An ovary may be one-celled, because it consists of but a single carpel; or, being *syncarpous*, it may contain an undivided cavity, from the obliteration of the partitions, or dissepiments, originally formed by the walls of the several adhering carpels. In this case the attachment of the ovules, or *placenta*, is either *central*, the ovules being clustered around a central column (as in Fig. 83, §. 434), or *parietal*, where they are attached to the outer wall (as in Fig. 84). Varieties of structure of this nature are very important in dis-

tinguishing orders. A peculiar enlargement of the receptacle, which sometimes expands between the bases of the carpels so as to separate them more or less completely (§. 470), as in the Strawberry, is often very characteristic of particular orders. The ripened ovary or fruit exhibits numerous and remarkable differences in its form, substance, and mode of dehiscence (or its manner of bursting when ripe); but these do not usually receive much attention from Botanists; since although there are a few orders which are characterized by a particular kind of fruit, most others present numerous varieties among their different genera.

500. Many valuable characters are drawn from the seed, both in its early and mature conditions. The number of ovules, —that is to say, whether they are definite or indefinite,—is frequently an important difference; still in some orders, there are genera nearly allied, in one of which the number is definite, whilst it is indefinite in the other. The position of the ovules is more essential than their number; the chief distinctions are between those which, rising upright from the base of the cavity, are termed *erect;* and those which, hanging from its top, are called *pendulous.* Between these two conditions, however, there are other intermediate ones. Such a difference in the position of the ovules often serves to mark a distinct line of separation between the plants of two groups that are otherwise nearly allied. In the perfect seed, the number of cotyledons is a character of primary importance, for distinguishing the two great classes of Phanerogamia, as already several times stated. Even this, however, is subject to occasional exceptions; for there are Endogenous Plants with two cotyledons, and some Exogens with only one, or even none; whilst again, some Exogens have several. As a means of distinguishing orders, the presence or absence of a separate albumen (§. 439) is a character of great value, especially when the embryo bears a very small proportion to it in amount, as in the orders we shall first have to consider. Where, however, the embryo and albumen are nearly equal in size, the character is of less importance; so that it is not uncommon to meet, in the same order, with some genera, of which the embryo alone fills the seed, and with others in which a part is occupied by albumen;

whilst in the orders especially characterized by it, there is probably not a single genus in which it is absent. It must be remembered that albumen exists in all seeds at an early period of their formation; and that the subsequent difference will depend upon the degree in which it is absorbed by the embryo.

501. The student, who has given attention to the preceding statements, is not unlikely to feel some perplexity, on account of the constant uncertainty which has been stated to attend the value of the several characters that have been enumerated. But as he proceeds further, he will find that this uncertainty is greater in appearance than in reality; and that it necessarily results from the properties of a Natural Group, as already described. In dividing the Vegetable Kingdom on an Artificial Method, it seems very easy to lay down a small number of characters as the standard; and to bring together, or to separate, Plants, according to their conformity or variety in these. But, as has been already shown, when we come to apply this plan, numerous difficulties are met with, in consequence of the differences which are of constant occurrence, among plants belonging to the same genus or even to the same species (§. 481); so that even here, the Botanist must be guided by *general* resemblance. Now, although it is quite true that no *single* characters, when traced throughout the Vegetable scale, can be relied on, as indicating the Natural Affinities of plants, yet experienced Botanists have little difficulty in defining each order, by a certain *combination* of characters which are peculiar to it; and not unfrequently, the plants belonging to one order may be separated from those of all other groups, by some evident and well-marked peculiarity.

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502. On the foregoing principles, the class of Exogens is divided by De Candolle in the following manner.

The first group consists of those, of which the Flowers possess both calyx and corolla, and in which the petals of the latter are distinct, and which are therefore *Polypetalous*. This group is divided into two Sub-classes, according to the mode of insertion of the stamens.

Sub-class 1. *Thalamifloræ.* Polypetalous Exogens, in which the stamens arise from the disk,—that is, are *hypogynous*. Sometimes the stamens adhere slightly to the sides of the ovary, but they are never epigynous, nor perigynous (§. 498).

Sub-class 2. *Calycifloræ.* Polypetalous Exogens, in which the stamens arise from the calyx or corolla,—that is, are *perigynous*.

In the next Sub-class, the flowers, still possessing both calyx and corolla, have the latter formed of united petals, or are *Monopetalous*. In this division, the position of the stamens is not regarded as a primary character.

Sub-class 3. *Corollifloræ.* Monopetalous Exogens.

In the lowest group, the corolla is always absent, making the flower *Apetalous;* and the calyx is not uniformly present. This character is regarded as sufficiently marking the group.

Sub-class 4. *Monochlamydeæ*, Apetalous Exogens.

The object of this classification is to proceed from what are considered the most perfectly-organised Exogens, to those which are least so. Thus all the parts are present and distinct from each other in *Thalamifloræ;* other things remaining the same, the stamens adhere to the perianth in *Calycifloræ;* the petals join together in *Corollifloræ;* and in *Monochlamydeæ* first the corolla disappears, and then, among the most imperfect orders the calyx ceases to be developed.

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503. The class of Endogens is not divided, by De Candolle, into any Sub-classes. It will, however, be convenient to consider their orders as characterised by the completeness or incompleteness of their flowers. The *Complete* Endogens may be again sub-divided into those with a *superior*, and those with an *inferior* ovarium. The orders having *Incomplete* flowers are separated into those, in which a cluster of flowers is inclosed in a single large bract, termed a *Spathe*, which is frequently coloured (as in the Arum tribe); and those in which the perianth of each flower is replaced by scale-like bracts, as in the Grasses.

CLASS I. EXOGENS.—SUB-CLASS I. THALAMIFLORÆ.

Order RANUNCULACEÆ, *or Crowfoot Tribe.*

504. If we examine the structure of the flower of the common Crowfoot or Buttercup, so abundant in our meadows as to be everywhere easily found, we shall observe the following to be the plan of its formation. Beneath the yellow petals, there may be seen *five* small greenish-yellow leaflets; these are the *sepals* of the calyx (§. 455): they fall off shortly after the flower opens. Within these are *five* other leafy organs, of a bright yellow colour on both sides, which give to the Buttercup its gay and glittering appearance; they stand up and form a little cup, in the bottom of which the other parts of the flower are curiously arranged; these are the *petals* of the corolla. At the base of each will be seen, on the inside, a little scale, from which honey exudes. Within the corolla are found a large number of stamens, with very short filaments; which, like the sepals and petals, are all separately implanted on the receptacle. Almost buried within the stamens, and occupying the centre of the flower, are a number of little green grains, collected as it were in a heap, and seated upon a small elevation of the receptacle, into which the stamens, petals, and sepals are all separately inserted. They are too small to be seen readily without a magnifying-glass; but when enlarged in that way, they are observed to be rounded at the bottom, and contracted into a sort of short bent horn at the top. Each of these is a single *carpel;* the horn-like projection is the *style* which it

FIG. 130.—FLOWER-STALK OF MEADOW CROWFOOT; on the right, an open flower and dry fruit; on the left. expanding buds; *a*, *a*, bracts; *b*, calyx.

bears; and the tip of this, which is rather more shining, and somewhat wider than the style itself, is the *stigma* (§. 434). Every one of these carpels contains a single ovule or young seed; it requires, however, some dexterity to make its contents apparent. The ovule when young, occupies but a small part of the cavity of the carpel; in time, however, it increases, so as to fill it completely. After the calyx, corolla, and stamens have fallen off, the cluster of carpels remains and ripens into the fruit of the plant. They undergo little change of form, though increasing in size; but they become dry, brown, and hard, resembling seeds. Though they are ordinarily taken for such, they are, as just shown, the seed-vessels, each containing but one seed. When this is the case, as it is in Corn, the carpels are termed *grains*. If the grain be cut through, nothing but a solid mass of white flesh will be met with, of which all the portions seem alike; unless the section have passed exactly through the centre, when there may be distinguished, near the base of the seed, a minute oval body, which may be taken out of the flesh upon the point of a needle. This oval body is the *embryo* of the young plant, with its two *cotyledons*; and it is embedded in a separate *albumen* (§. 439).

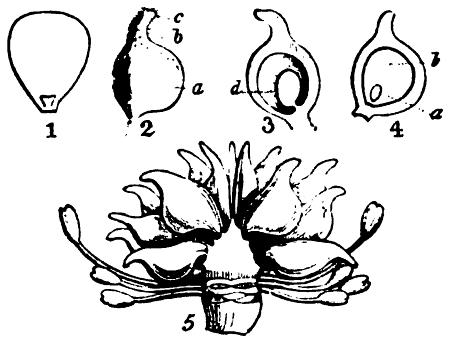

FIG. 131.—PARTS OF THE FLOWER OF THE COMMON RANUNCULUS, OR BUTTERCUP. 1, one of the petals, with the scale at the bottom on the inner side; 2, one of the carpels, showing *a*, the ovary, *b*, the style, and *c*, the stigma: 3, section of the unripe carpel, showing *d*, the ovule within it; 4, section of the mature carpel filled with the seed—*a*, the embryo, *b*, the albumen; 5, the carpels and some of the stamens, implanted on the receptacle.

505. On looking at other parts of the plant, it will be observed that the leaves are dark-green; and that they are very much divided by deep indentations. It will further be re-

marked that their form is simpler at the upper part of the stem than near the root; the lobes or chief divisions being narrow, and not themselves divided, in the former case; whilst in the latter they are more expanded, and their edges are deeply cleft. At the bottom of the flower-stalk may be observed a couple of small leafy bodies, which are the *bracts* (§. 457). These, as formerly stated, are intermediate in character between the true leaves and the leafy portions of the flower; and of this fact the species under observation affords a remarkable illustration. Two specimens, pulled at random from the nearest field, are now before the writer; in one the bracts are simple in their form, like the sepals of the calyx; in the other they are cleft into three lobes, and more resemble ordinary leaves.

506. Now the foregoing characters are those, by which the order RANUNCULACEÆ is separated from other tribes; but they are *not all* presented by every plant which, on account of its *general* resemblance, is placed in the same group with the common Crowfoot. For example, there are some which have 3 or 6 sepals in their calyx, instead of 5, the regular number. The petals, again, are sometimes more numerous than 5, and sometimes altogether wanting. The number of stamens is quite indefinite. That of the styles is also variable, since the styles of the different carpels may unite into a single one, or into a small number, or may remain (as in the common Ranunculus) entirely distinct. The number of seeds in each carpel is not restricted to one. It will be asked then,—what are the *essential* characters by which this natural group is marked? They are simply these. The stamens are numerous, and arise from the disk beneath the carpels; and the carpels are themselves distinct.* The structure of the other parts of the flower may or may not be conformable to that of the common Ranunculus; and it is in fact by the minor variations, that the order is subdivided into genera. The greatest apparent resemblance of the flowers of this group,

* This last character is occasionally subject to exception, the carpels being more or less united in some species; but other characters of resemblance then come to the assistance of the Botanist, and enable him to determine the place of these species in the order.

is to those of Rosaceæ; but they may be at once distinguished by the position of the stamens, which in the latter, are adherent to the calyx, instead of arising at once from the receptacle.

507. All the plants agreeing in these general characters, also agree in their properties; for their juice is constantly acrid and nauseous, though in a degree which varies in the different species. In some of them, there is also a certain amount of a narcotic principle. These properties cause several species to be useful in medicine, as will be presently noticed; but they prevent them from being of much utility as food, causing them to be usually rejected by cattle, which eagerly devour the harmless plants around. The Ranunculaceæ further agree in being either herbaceous or shrubby plants, never rising to the dignity of standard trees.

508. Of the *Ranunculus* itself, many species are natives of Britain. Among the commonest are the *R. acris* of our meadows, and the *R. sceleratus*, or Celery-leaved Crowfoot, of the sides of pools and ditches. Both these derive their specific names from the acridity of their juices, which excoriate the skin, and even form ulcers that are difficult to heal; and the simply holding specimens in the hand for a short time, will sometimes inflame its surface. The *R. aquatilis*, or Water-Crowfoot, is one of the least virulent of the order; and in some parts of the country, where it abounds, it is employed by cottagers as a fodder for cows and even horses. There is a curious distinction between the leaves of this species, some being submersed beneath the water in which the plant grows, whilst others float upon its surface; the former are subdivided into a large number of rounded hair-like filaments; whilst the latter are but little separated into lobes. Some foreign species of Ranunculus are much cultivated in gardens, on account of the beauty of their flowers, which have a tendency to become *double*, that is, to have one or more additional whorls of petals developed within the ordinary corolla, at the expense of a corresponding number of stamens.

509. To this group also belong the well-known *Anemonies*, whose flowers are so attractive with their white, blue, or purple

petals, on wooded banks. In these the petals and sepals cannot be distinguished, the whole perianth being coloured alike. They exhibit a remarkable tendency to variation in the character of the flower, usually depending upon the amount of nutriment which the plant receives (§. 461). Sometimes the sepals revert to the form of ordinary leaves, whilst the petals exhibit a greenish tinge, and the stamens of the outer row approach the petals in character. The transformation may extend farther inwards,—the petals becoming quite green, the outer stamens resembling ordinary petals, and the inner ones presenting an approach to the same form. Every shade and variety of metamorphosis may be met with, until all the parts of the flower, carpels as well as stamens, are found to have been transformed into leaves, of which the inner ones are most simple, whilst the several whorls change in their character towards the form of the exterior one, which corresponds with that of the ordinary leaves of the plant. —When the flower of the Anemone has dropped off, there is seen in its place a little tuft of feathery tails or oval woolly heads, in place of the clusters of grains which are found in the Ranunculus. These tails are nothing but the styles of the carpels, grown large and hairy; they probably serve the purpose of *wings* by the action of the wind upon which, the carpels containing the seed are dispersed.—The *Hepaticas* differ little from Anemonies; they were once in repute for their supposed medicinal virtues in diseases of the liver; but they are now esteemed merely as ornamental garden plants, and it is curious that they may often be seen to thrive when neglected in a cottage garden, whilst they perish under greater care, as if they were created specially for the pleasure of the poor.

510. Another subdivision of the order is that which contains the *Clematis*, a genus of climbing plants, of which the species native to Britain is known under the name of Traveller's Joy; whilst another, which is much cultivated in gardens, is commonly called Virgin's Bower. These are almost the only plants of the order which form woody stems; they grow in hedges and against walls, their petioles being prolonged as tendrils; and, in spite of the acridity of their juices, their flowers are mostly fragrant.

511. A group which departs more widely from the ordinary characters of the tribe, is that which includes the *Hellebores* and their allies. The irregularity of these chiefly lies in the petals and stamens. In the *Trollius*, or globe-flower, which inhabits moist mountain pastures in this country, and is conspicuous with its large handsome flowers, the petals are contracted into little linear bodies, scarcely exceeding the stamens in size; and it is to the petalline character of the sepals, which are usually about 15 in number, that their showy aspect is due. The *Caltha*, or Marsh Marigold, which grows in large tufts in wet meadows and by the sides of ditches, has no petals at all. The common *Green Hellebore*, abundant in woods, thickets, and hedges, especially in calcareous soils, and the *Stinking Hellebore*, a bushy plant of similar habits, are easily known by their large greenish-yellow sepals, and their small tubular petals. A foreign species of Hellebore is cultivated in our gardens under the name of Christmas Rose; here the substitution of petals for stamens, and the general aspect of the plant, make the resemblance to the order Rosaceæ very striking; but the flowers are easily distinguished by the characters already mentioned. The Hellebores were formerly in great repute for their medicinal virtues, especially in the cure of mental derangement. The Black Hellebore of the ancients grew plentifully near Anticyra, a city of Phocis in Greece; whence arose the proverb, applied to any one who acted in an absurd manner,—"Naviget Anticyram," "Let him sail to Anticyra." They are now disused, however, as their purgative properties are so violent, as to render their employment dangerous. The *Aquilegia* or Columbine, and *Delphinium*, or Larkspur, belong to this group; a species of each genus is a native of Britain; but others with much more showy flowers, obtained from abroad, are cultivated in our gardens. They are both distinguished by great irregularity in the petals, these having long tubular spurs, of which the small scale at the bottom of the petal of the Ranunculus may be considered as the rudiment; and in the latter, the several petals differ in form, two only being spurred; and one of the sepals of the calyx has a horn, in which the two spurs are hidden. Both these plants

have been employed in medicine, but are now disused for the same reason as the Hellebores.

512. The most irregular of all the flowers we have to notice in this order, is that of the common *Aconite*, ordinarily known as Wolf's-bane or Monk's-hood, which is occasionally found wild in this country, although it has probably escaped from gardens, in which it is much cultivated, on account of its showy aspect. The sepals of this flower are purple-coloured, like petals; and one of the five is very large, resembling a sort of helmet, and overshadowing all the other parts of the flower. Of the petals only two are developed; and these are so much changed in form, that they would be scarcely recognised as such; they are two fleshy bodies, mounted upon long stalks, projecting into the hollow of the helmet-shaped sepal. Three other abortive petals may generally be detected as little scales, when the calyx has been removed. The leaves and roots of the Aconite contain more of the narcotic principle than those of other plants of this order: if the former be chewed for a few minutes, a curious tingling sensation is experienced in the lips, showing that the nervous system is immediately affected. The extract made from them has been used with good effect in many nervous diseases; but in making it great precaution is required, as its properties are destroyed by a very moderate degree of heat. In this respect, the rest of the tribe resemble it; and the leaves of many, which would be very poisonous when fresh, may be rendered wholesome food for cattle by drying them with moderate warmth.

513. The *Pæonies*, much cultivated in our gardens, on account of their showy flowers, are generally considered as belonging to the Crowfoot tribe, although differing from it in some important particulars. Of these we may notice that the calyx, instead of dropping off at an early period, as in most of the order, lasts as long as the flower-stalk itself; and the carpels, instead of being numerous, are diminished to 5 or even 2, containing, however, many seeds, and having an elongated form. In the species which is wild in Britain (though only met with in one or two localities) there is only a single row of petals; but, as in the

Anemone and many plants of this tribe, the cultivated species have the number very much increased, so that the stamens may be even entirely replaced by them, and the outer ones then approach the sepals in character. The gradual transition in the form of the leafy parts, between the lower portion of the plant, and the centre of the flower, which may readily be observed in the common Garden Pæony, has been already noticed (§.457-9).

514. As a considerable number of stamens is characteristic of the plants of the order of Ranunculaceæ, when not modified by cultivation, they mostly belong to the Linnæan class POLYANDRIA. The orders of this class under which they are included, are different, according to the number of styles which are developed. One British genus (*Actæa*, Bane-berry) allied to the Pæonies, has but a single carpel and style, and therefore belongs to the order *Monogynia*, where it is associated with the plants of the Poppy tribe. The Pæonies, Hellebores, Larkspurs, Columbines, and Aconites, have styles varying in number from 2 to 6, and are placed in the order *Pentagynia* (*five*-styled),—an example of the very loose and indefinite application of terms in this kind of classification. The only British genus associated with them in this order is the *Stratiotes* or Water-Soldier, so named from its sword-shaped leaves, which is an Endogenous plant belonging to the Frog-bit tribe. The Ranunculus, Anemone, Clematis, Marsh-Marigold, and their allies, having a large number of styles, are placed together in the order *Polygynia*, which contains no other British genus.

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515. Succeeding the Ranunculaceæ in a natural arrangement, is an order apparently very different from it, of which a brief mention will suffice. This is the splendid *Magnolia* tribe, of which no species are natives of this country, but of which more than one has been introduced into gardens; and, although natives of warm climates, they thrive well in the milder parts of Britain, if protected by a wall. The Magnolias are for the most part large and beautiful trees, sometimes attaining the height of 90 feet, and surpassing almost all the other denizens of

the forest in their superb foliage, (the leaves sometimes attaining the length of three feet), and in their magnificent goblet-shaped flowers, that look as if they were chiselled out of alabaster. The East Indian species are most remarkable for the perfume they diffuse. It would scarcely be supposed, that these princes of the Vegetable kingdom should be allied to the humble Crowfoots we have been just considering; and yet the structure of their flowers shows them to be so. The Magnolia has a calyx of three small sepals, and a corolla of six petals; these numbers, though varied in the different genera, are usually multiples of three. The stamens are numerous, and arise immediately from the receptacle. In the centre of the flower there are a large number of carpels, each containing a distinct cell, and terminated by a narrow thread-shaped stigma. In no essential point, then, does the flower of the Magnolia, as yet described, differ from that of the Ranunculaceæ; there is this important variation, however,—that the carpels of the former grow together in some degree, so that the fruit, instead of consisting of a cluster of grains, as in most of the Ranunculaceæ, appears as a solid cone.

516. There is a more important difference, however, in the leafy parts of the tree. There may be found in many plants, at the base of each leaf-stalk, a pair of small leafy bodies, which are called *stipules*, and which are to the leaves very much what the bracts are to the flowers. In the Magnolia the stipules are large, and perform an important function, to which there is nothing analogous in the Ranunculaceæ. Each of its branches is terminated by a little horn-like projection, springing from the base of the last leaf; this horn is a pair of stipules, rolled together for the protection of the next leaf that is to be unfolded. That and the next leaf has a similar pair of stipules, which roll up over the still younger leaf lying at the base of its yet undeveloped petiole; and if the horn be cut through, several generations of leaves will be found thus enfolded one within the other. This is a characteristic peculiarity of the Magnolia tribe; and it has an interesting relation with the circumstances of its growth; for the bud is peculiarly tender, and requires to be protected from

cold and accidents. In other plants we meet with different provisions for this purpose; in this instance the stipules are made to perform the business of protection. The different parts of the plant, in all the known species of this order, contain, in greater or less degree, a bitter principle, which has been successfully used in medicine as a tonic, particularly in North America, where this tribe most abounds; but it is not employed in this country.

517. Allied to the Magnolia tribe is the order ANONACEÆ, or *Custard-Apple* tribe, which is confined to tropical climates; it

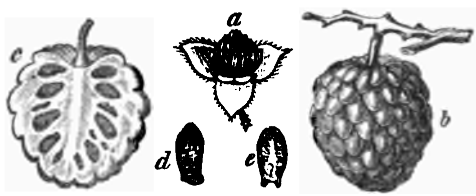

FIG. 132.—ANONA SQUAMOSA, OR CUSTARD-APPLE: *a*, the flower; *b*, fruit; *c*, the same in section, showing the position of the seeds; *d*, seed; *e*, section of the seed.

is best distinguished by the structure of its seed, the innermost coat of which forms several plaits or folds, that enter the albumen. The Custard-Apple of the East and West Indies is a refreshing fruit, combining an agreeable acidity with sweetness; other species of the order have aromatic properties.

518. Another tropical order, intermediate between this and the one to be next mentioned, is that of MENISPERMACEÆ, the *Cocculus* tribe. These are twining shrubby plants, chiefly distinguished by the deficiency of parts in their flowers, which are constantly unisexual (the stamens and pistils never being developed in the same flower), and are sometimes diœcious (§. 435). The number of carpels varies considerably, as does also their degree of adhesion; so that it is altogether difficult to characterise the order, the different genera of which, however, correspond remarkably in the medicinal characters that render it chiefly interesting. The root is bitter and aromatic; that commonly known as Columbo root is much employed in this country

as a tonic and stomachic; and that of other species is used for the same purpose, in the countries of which they are respectively natives. On the other hand, the seeds of most of them are narcotic, in various degrees. The drug named Cocculus Indicus is the seed of an Indian Menispermum; it has been much employed by brewers in this country to heighten the intoxicating properties of their malt liquor, so that it is now illegal for a brewer even to have the article in his possession; it has also been employed by poachers to capture fish, which it causes to become powerless and to float on the water. A large quantity is imported into this country, in spite of the illicit nature of the uses to which alone it can be applied.

519. Another interesting order, possessing the same general structure, but having very different properties, is that of BERBERIDEÆ, represented in Britain by the common *Berberry*, a shrubby plant, frequent in hedges and plantations, and well known from the bunches of red succulent acid fruit which it bears. The branches of this bush are covered with sharp spines, in sets of three or more; and from the base of each set the leaves arise. Now these spines are nothing else than the hardened veins of the first-produced leaves of each bud, between which the fleshy tissue is not developed (§. 236); and this will become evident, on looking at a very vigorous shoot of the plant, which will exhibit at some points the space nearly filled up with parenchyma; at others partly so; and at others, the spines entirely bare. This is not, however, an universal character of the *order;* but it is one which marks the common *species* before us, as well as many others. The flowers present several interesting peculiarities. Their parts are generally arranged in threes, the number of sepals, petals, and stamens, being six in the common Berberry. The anthers open by *valves*, in the manner formerly described (§. 432), which character is sufficiently distinctive of this order; and the stamens possess a curious irritability, which also has been already noticed (§. 421). The position of the stamens is peculiar, being *opposite* to the petals,—a character which the Menispermeæ share with them (§. 463—5). The ovary consists of only a single carpel, containing from one to three seeds; and it is this

which in time changes to the oblong scarlet berry of the common Berberry, which genus of course belongs to the Linnæan class

FIG. 133.—EPIMEDIUM ALPINUM, AND BERBERIS SIBERICA.

HEXANDRIA, and order *Monoggnia*. The British *Epimedium* or Barren-wort, however, possessing only four stamens, is referred to the class TETRANDRIA; but there is a North American species which conforms to the general type in possessing six stamens.

520. Another order which may be briefly noticed, is that of NYMPHACEÆ, the Water-Lily tribe; the two common species of which,—the White and Yellow Water-Lily (belonging, however, to different genera)—are sufficiently well known. Much controversy has taken place, as to whether this order is to be ranked among Exogens or Endogens, as its herbaceous stem does not afford the means of satisfactory determination, and the structure of its leaves is such as might agree with either group. Here, however, the *number* of the parts of the flower, which are arranged in *fives*, affords important assistance; and, in spite of some general resemblance which the Water-Lilies bear to the Water-Plantains, this fact would lead us to rank the order with Exogens, of which the number five is characteristic, whilst it never presents itself in Endogens. The structure of the seed confirms this conclusion; for the embryo is a little dicotyledonous body, enclosed in a peculiar bag which separates it from the

albumen; this bag has been mistaken for a cotyledon, wrapping round the embryo, whose real cotyledons were overlooked; so that the seed has been erroneously considered monocotyledonous.

521. The flower of the White Water-Lily offers many points of interest. It consists of about twenty-five thickish oblong leaves of a white colour, arranged in whorls of five each; the five external ones are green at the back, and may be regarded as forming the calyx; towards the interior of the flower, the petals gradually become smaller, and are tipped with yellow at their points, which are thickened. From these a very gradual transition takes place towards the form of the stamen, as heretofore described (§. 460); and the inner rows of stamens (which are usually all together about 50 in number) shorten and produce less perfect anthers. The ovary has the lower floral leaves adherent to it, so that the stamens appear to arise from just below the stigmas. It consists of ten or eleven distinct carpels, which adhere closely together; their several walls still forming complete partitions in the ovary, each chamber or cell of which contains a large number of ovules. The ovary is surmounted by a number of orange-coloured stigmas, radiating from the centre, very much as in the Poppy; but as they are all united at the centre, they are considered as forming but a single pistil; and the plants of this order are therefore arranged, with those of the Poppy tribe, in the Linnæan class and order POLYANDRIA *Monogynia*. They agree in possessing some bitterness and astringency in their juices; and also in being all floating plants. They are most abundant in the northern hemisphere, and have been said to be entirely absent from South America; but a species has been recently discovered there, which in size and splendour far surpasses all others. This is the *Victoria regalis;* of which the leaf is from 5 to 6 feet in diameter, salver-shaped, with a rim rising from its edge, of from 3 to 5 inches high, green inside and crimson on the exterior. The flower is of proportional dimensions, the expanded calyx sometimes attaining a diameter of 23 inches; this contains several hundred petals, which are at first of a white hue, passing gradually towards pink in the centre, and those nearest it becoming pink throughout. As in the common

White Water-Lily, the petals gradually change into stamens towards the interior of the flower; those next the calyx are fleshy and contain air-cells, which must contribute towards the buoyancy of the flower. Their sweet scent enhances its beauty.

522. The small Order FUMARIACEÆ, or *Fumitory* tribe, is chiefly deserving of notice, on account of its containing some British species, of which one is among our most common wild plants. Their flowers are remarkable for only possessing two sepals in the calyx, and four petals which are parallel to each other, the outer one having a little cavity or pocket near its base; they are also remarkable for never completely unfolding, the inner petals remaining adherent at the top, so as to enclose the anthers and stigma. The stamens are six, and are united into two parcels, whence the family belongs to the Linnæan class DIADELPHIA. The ovarium contains but a single cell, being formed by only one carpel, or by the union of two without a partition; and the ovules, which are sometimes single and sometimes numerous, are attached in a horizontal direction. This order, which is principally found in the temperate latitudes of the northern hemisphere, is characterised by no properties worthy of special notice.

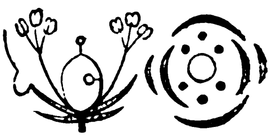

FIG. 134.

FIG. 135.—FUMARIA LUTEA.

Order Papaveraceæ *or Poppy Tribe.*

523. The common British species of this order are well known as the plague of the farmer, coming up as rank weeds in his corn-field; and another species is important as yielding a product, which, used with discretion, is one of the most valuable medicines we possess, but which, by the folly of Man, has become the bane of millions. If any of the common species of Poppy be examined, they will be found to bear a considerable general resemblance to the Ranunculaceæ. The leaves are much divided, and the stamens are numerous, arising from under the carpels. Unlike the Crowfoot and its allies, however, the carpels are not separate from one another, but are united together into a single ovarium; no styles are present; and the stigmas are elevated hairy lines, which spread equally from the top of the ovary, forming a sort of star-like crown. If the ovary be opened, it will be found to contain but one cell or cavity;—several little partitions, however, project from the sides towards the centre; and

Fig. 136.—Leaf and Flower of the Naked-stalked Poppy, exhibiting the four petals, numerous stamens, and single ovary.

Fig. 137.—Parts of the Flower enlarged; 1, a flower bud, showing the two sepals which enclose it; 2, the ovary with its radiating stigmas; 3, the ovary cut open.

these are covered with numerous and very small ovules or young seeds. The common Poppy has a calyx of only two sepals, which completely inclose the bud before it expands; and within this is a corolla of four petals. Some of the tribe, however, possess three sepals and six petals; but the former is the ordinary number. If the stem or leaf of a Poppy be broken, a milky juice runs out; and its whiteness is due to the narcotic substance, *opium*, which is diffused through it; and also, perhaps, to a larger proportion of Caoutchouc than most Vegetable juices contain. The Crowfoot tribe have a clear juice; and this difference, connected as it is with a great difference in the properties of the respective groups of plants, is a very characteristic one. But independently of this, the well-marked difference in the construction of the ovary, takes away all difficulty in distinguishing these two orders from each other.

524. The calyx very early falls off,—a character by which this order may be distinguished from others of less importance. As the ovary ripens, the exterior becomes very hard and brittle, forming a hollow box termed a *capsule*, with a brownish-yellow shell. The seeds, when mature, separate from their attachments, and may be shaken loosely in their case. In this condition, the capsules are well known as Poppy-heads, being kept in druggists' shops, on account of the mild narcotic properties, which give the water in which they have been boiled some soothing effects when applied as a fomentation. So hard and firm is the shell of the capsule, that the seeds could not find their way out, unless permitted to do so by a particular contrivance. Just beneath the lid, which is firmly bound down to the lower part by the hardened stigmas, there is a set of little valves, which open in the intervals of these (as shown at 2, Fig. 137): and through these, the seeds fall out. The structure of the Poppy-capsule is easily understood, by imagining that the several carpels have adhered together, their walls being flattened against each other, just as in the Orange; but that the central portion formed by the union of these has not been developed, so that the partitions are incomplete, though still projecting more from the sides, than they do in the Heartsease (§. 434, Fig. 84). In each case, as the seeds

are attached to a placenta, which springs from the wall, and not from the centre of the seed-vessel, the placenta is said to be *parietal*. In the true Poppies, the number of placentæ, marking the number of united carpels, is considerable; but in a British genus *(Glaucium)* commonly known as the Horned Poppy, the ovary is formed of only two carpels grown together; and these, when ripe, look like long slender but stiff horns, whence the *common* name is derived. The *scientific* name is founded on the sea-green hue of the stems and leaves, which look as if the surface had been encrusted with the salt spray. Allied to the Horned Poppy (which grows chiefly on the sea-shore) is a plant termed Celandine *(Chelidonium)*, having pale green leaves and rather small yellow flowers which grow in umbels (as in the tribe of *Umbelliferæ*, hereafter to be described), and frequenting waste places, especially near towns and villages. This still more departs from the ordinary type of the Poppy tribe, in the structure of its seed-vessel; which consists of a single pod separating when ripe into two valves, as in the Pea tribe.

525. A very curious anomaly is met with in a foreign genus belonging to this order, the *Eschscholtzia*. The flower of this plant, before it expands, is enclosed in a taper-pointed green sheath, which is pushed off by degrees as the petals unfold, and at last drops to the ground. This extinguisher-like organ would seem to be something entirely new. If carefully examined, however, it is found to be nothing else than the calyx, of which the two sepals have adhered so firmly, that they will not separate, in the ordinary manner, to admit of the expansion of the flower; and as it must be got rid of in some way, nature has provided the means of throwing it off, by making its attachment weak at the base, from which it is disengaged. This adhesion of two parts growing in contact with each other, is a very common occurrence in Plants; and several instances of it will hereafter occur.

526. The plants of this order exhibit, in a greater or less degree, the same tendency to variation, which has been noticed in the Ranunculaceæ. This is especially the case with the White Poppy, which is cultivated in gardens on account of the showy

appearance of its flowers, when several additional whorls of petals have been developed at the expense of the stamens. Its colour, also, has a tendency to change, but generally to light shades of purple. The deep scarlet Poppies, so abundant in corn-fields, are not so prone to variation.

527. All the Papaveraceæ possess narcotic properties in more or less intensity; but these properties are not common to the whole plant, being only manifested by those parts which abound in the milky juice. Thus from the petals of the Red Poppy a syrup is made, which is used to colour medicines, on account of its beautiful deep-red hue; but this is perfectly destitute of medicinal properties. The seeds, again, yield a large quantity of a fixed oil, which is quite free from any narcotic quality (§. 371). From the ripening capsules, however, especially of the White Poppy, the milky juice may be obtained in large quantities; and it is from this source that all the *opium*, obtained for medicinal and other purposes, is derived. The properties of this drug, and the enormous amount of it consumed, have been already remarked upon (§. 384—5); and the account need not here be repeated. It may be desirable to mention, however, that a syrup is made from the *White* as well as from the *Red* Poppy; and that the former possesses narcotic properties, from which the latter is wholly free. It should be used, therefore, by unprofessional persons with great caution. There is too much reason to believe, that the lives of many infants have been destroyed, by the administration of tea-spoonful after tea-spoonful of White-Poppy Syrup, given by ignorant nurses or mothers, with the idea of temporarily soothing them. And it is also well known, that the injudicious use of many excellent popular medicines, into the composition of which opium enters in unknown quantity (such as Godfrey's Cordial, and Daffy's Elixir), has been productive of equally fatal effects. It cannot be too strongly impressed on those who have the management of infants, that they are susceptible of the influence of narcotics in a far higher degree, than of that of purgative and other medicines; so that whilst an infant may safely take a grain of calomel, or three or four of jalap,—one-fifth of the ordinary doses for adults,—a single drop

of laudanum is as much as it is usually safe to give, the dose for an adult being twenty times as much.

528. All the Papaveraceæ belong to the Linnæan Class Polyandria, and to the order *Monogynia;* the style being apparently single, though formed by the union of many.

Order Cruciferæ, *or Turnip Tribe.*

529. This order is one of the most important to Man, in respect to the amount of wholesome food which he directly or indirectly derives from it, of the entire group of Exogens. It comprehends the Turnip, Cabbage, Sea Kale, Mustard, Cress, Radish, and other edible Vegetables; as well as the Rape, cultivated for the oil yielded by its seed; and Stocks and Wallflowers, valued as showy garden-plants. As the flowers are generally small, there might be some difficulty in recognising them; were it not that they are marked by very obvious characters, which are easily observed, and can scarcely be mistaken. One of these characters is derived from the number and arrangement of the stamens; which throughout the whole of this order are scarcely subject to variation, and which are not presented by any plants that do not belong to it. The number of stamens is six; but four of these are longer than the rest; so that they would be characterised in Linnæan classification as *tetradynamous* (§. 483); and in fact the Linnæan class Tetradynamia, and this order *Cruciferæ*, correspond precisely. The arrangement of these stamens, somewhat in the form of a Maltese cross, is another peculiarity, from which the name of the order is derived; the four long stamens are placed above and below, and the two shorter ones at the sides. Some other less constant characters will be noticed as we proceed.

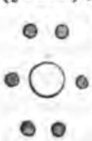

Fig. 138.

530. A good example of this Order will be found in a common weed, named *Shepherd's Purse* (Capsella Bursa pastoris), which may be found almost everywhere, and at all but the coldest seasons of the year. Its name seems to have been derived

from its possessing a number of pouches, filled with very small seeds, which might be imagined to be fairy coins. The flowers, in this plant, are arranged upon the stem in the form which is termed a *raceme;* by which it is meant, that they spring from it by short stalks nearly of equal length, which arise at intervals; a bunch of Currants is a very good illustration of this form. It will be observed that they are destitute of bracts; the entire absence of which is a peculiarity of this order; although many genera of other orders are also distinguished by it. The calyx is formed of four little sepals; and within these are four very small white petals; the regular arrangement of which increases the cross-like aspect of the flower. The stamens alternate with the petals, and are opposite the sepals. The pistil is an oval green body, shaped something like a wedge; on the summit of which is a cushion-like stigma, mounted on an extremely short style. If the ovary be cut open, it will be found to contain two cells, each of which includes a number of ovules hanging by slender thread-like stalks. It will be observed, however, that the ovules do not originate from one central placenta, but from one attached to each side-wall of the ovary; and this explains to us (as will presently appear) the reason why the ovary is very often one-celled in this order, and also the peculiar mode of dehiscence of the seed-vessel. The fruit becomes a flat wedge-shaped body, composed of three pieces, two of which, the *valves*, separate from the third, which is named the *dissepiment;* and it is to the edges of this third piece that the seeds are united. Now each valve is a carpellary leaf, the two

FIG. 139.—SHEPHERD'S PURSE; A, whole flower enlarged; B, stamens and pistil; C, horizontal section of ovarium.

edges of which are not entirely folded in; and the ovules arise, therefore, from a placenta formed by the thickened edges of each leaf, so that there are really four separate placentæ, as is indicated by the four different directions in which the ovules lie (Fig. 140, C). But the contiguous placentæ of the two carpels unite together, and project towards the middle of the ovarium; and in this instance the opposite ones meet each other, so as to form a complete partition. In many Cruciferous plants, on the other hand, they do not meet; so that the ovary is one-celled, and as the ovules are attached to its sides, the placentæ are said to be parietal. The form of the fruit differs in the different genera of the order; being, as formerly explained in the Linnæan Classification (§. 483), sometimes, as in the present instance, a short pod or *silicula;* and sometimes a long pod or *siliqua*, as in the Turnip and Cabbage, Stock, and Wall-flower. This distinction is not employed, however, to subdivide the order in the Natural system; since it is not found to bring together the plants that have really the nearest alliance: and Botanists found their classification of the genera (which, on account of their great number, need to be associated in groups) upon certain minute distinctions presented by the embryo. Throughout the order, however, the structure of the seed is different from that which has been elsewhere seen; for it is entirely destitute of albumen; and the embryo is doubled upon itself. (Fig. 140, D).

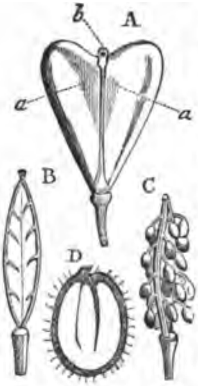

FIG. 140.—A, ripe fruit; *a, a*, the valves; *b*, the dissepiment. B, dissepiment seen in front, with the marks of the places to which the seeds are attached; C, dissepiment with seeds attached; D, section of seed.

531. All the plants of this order are herbaceous, and most of them are annual. The flowers are usually yellow or white, less commonly purple. It is remarkable that, whilst the characters of the order are so constant, those of the individual are liable to such great variation. This is evident in the species which are cultivated for the beauty of their blossoms, such as the Stock

and Wall-flower; as long as the flowers remain single, however, they are not valued by the florist; but it is their tendency to become double, by the development of petals in the place of stamens and pistils, that gives them their richness of appearance. If *all* the organs of fructification, however, were to undergo this conversion, there would be no means of propagating any particular variety or race which it might be desired to perpetuate. But among the petals, a perfect stamen or two will frequently be found; and in another flower an untransformed pistil may present itself; if the stigma of the latter be touched with the pollen of the former, the ovules will be fertilised, and seeds will be produced: these, if placed in a rich soil, will have a tendency to develop flowers of a similar character; but if sown in a barren place, like that which the wild plants inhabit, will probably bear flowers resembling theirs. If, on the other hand, the seeds of a flower departing too widely from the double form, be raised, its flowers will probably be alike imperfect. It is by attention to these rules, that the different races of Turnips, Radishes, &c. have been preserved; whereas if the seeds of those which do not perfectly exhibit the respective characters of the races, had been used for propagating them, they would all have returned in time to their original common form.

532. It is this tendency to variation under the influence of cultivation, producing the effect valued by the florist in the Stock and Wall-flower, which renders other plants of this order valuable to Man as articles of food. There is a remarkable tendency in many of them, to increase the amount of the fleshy portion of their tissues, when abundantly supplied with nourishment. This increase takes place in different parts, in different species. Thus in the Turnip and Radish it is chiefly in the root, the natural form of which is often completely changed by cultivation; yet the seeds of any variety of either of these species, if raised in a poor soil, will produce the tough stringy roots characteristic of the original wild plants. In the Cabbage and Sea-Kale, it is chiefly in the stems, leaf-stalks, and leaves; as is also the case in a less degree with the Turnip. The varieties of the Cabbage are very numerous;—the Scotch-Kale, the Savoy, the

Cauliflower, and Brocoli, are well-known forms, departing more or less from the orginal stock, the *Brassica oleracea* or Sea-colewort, which may be found growing wild on the cliffs, near the shores of the greatest part of South Britain, bearing a few small scattered leaves and meagre blossoms. In the Cauliflower, the part most prized as food consists of the flower-stalks, which are enlarged and become succulent under cultivation; when cut for the table, the flowers have not expanded. Some varieties of the Cabbage attain a great size. The Palm-kale, which is extensively cultivated in the Channel islands, grows to the height of 10 or 12 feet, the stem being very much elongated and bearing leaves only at its summit, so as to give the plant very much the aspect of a Palm; the inner bud is tender and palatable, and the outer leaves are given as fodder to Cattle. The Tree-kale or Cæsarean Cow-cabbage, is said to grow to the height of 16 feet, in some parts of France, where it is cultivated for the same purpose.

533. The Sea-Kale is obtained from another marine species, the *Crambe maritima;* the young shoots of which have, time out of mind, been collected by peasants, and eaten as a pot-herb; but which has only within a recent period become a cheap and common vegetable. In order to prevent it from becoming rank, by the too-abundant formation of its peculiar bitter secretion, and stringy, by the production of too many woody bundles, it is necessary to grow it almost in darkness (§. 362); and this is commonly effected by heaping up earth around the young shoots. A species of Brassica nearly allied to the Turnip, is that which furnishes the Rape-seed, from which a large quantity of oil is obtained by pressure; whilst the remaining fleshy substance, known under the name of oil-cake, is a very nutritious food for cattle. In all the seeds of Cruciferæ, there is a tendency to the deposition of a fixed oil in the cells (§. 371); and this deposite is greatly increased by cultivation in the seeds of this and other species.

534. Among other well-known British species of this order may be mentioned the numerous kinds of Mustard, Cress, Scurvy-grass, Horse-radish, Pepper-wort, and Lady's Smock,

or Bitter Cress. Of this last kind, the common meadow species (*Cardamine pratensis*) has a considerable tendency to become double; and when its power of reproduction is thus impaired, it has a very curious mode of compensation. The leaflets, whilst still in connection with the parent plant, will strike root into the ground, wherever they come into contact with it; and from each a new plant may arise. The *Isatis sativa*, from which the blue dye *woad* is obtained (§. 390), is another native species of this order.

535. The plants of this order are more abundant in Europe than in any other quarter of the globe; and a very large proportion of them are natives of the temperate zones. Their general character is to possess in some degree acrid and stimulating qualities, such as we meet with in the Mustard, Cress, Radish, Horse-Radish, Pepperwort, &c. When this acrid secretion is dispersed, however, through a large amount of fleshy tissue, as in the Turnip, Cabbage, &c., it does not prevent the plants from being palatable as well as wholesome food. None of this order can be said to be poisonous; and most of the species it contains are very useful remedies for a most distressing malady, the Scurvy, which was formerly not unfrequent in this country, when all but the highest classes fed upon salt meat during the greatest part of the year; and which has been, until the late improvements in the provisioning of ships, a most dreadful scourge to the crews of vessels undertaking long voyages. The name *Scurvy-grass*, by which the genus *Cochlearia* is commonly known, shows the estimation in which it was formerly held in this country, as a remedy for this disease; and other species are still more efficacious. There could scarcely, perhaps, be mentioned a more striking illustration of the practical utility of which the Natural System may be rendered, than a fact which occurred at the beginning of the last century. During Lord Anson's voyage round the world, a very large proportion of his crew either lost their lives, or were rendered unfit for service, by the Scurvy; and although new and unknown lands, teeming with luxurious vegetation, were constantly being discovered, the dread which the surgeon entertained of the men being poisoned

was so great, that he would often allow them to use no other kind of fresh vegetable food than grass. If he had been acquainted with the simple fact, that none of the Cruciferæ are deleterious, and that all possess (in a greater or less degree) those properties which render them more valuable than any ordinary medicines in the treatment of this disease, he might have been able to restore many to health, by simply explaining to them the very evident marks by which this order is characterised, and encouraging them to seek for plants which exhibit such, and to make use of them without apprehension.

536. The Order Cistaceæ, or *Rock-Rose* tribe, must next be mentioned. Although not a numerous or very important group, it presents several points of interest. The plants it contains flourish in dry rocky places, where others would not find a due supply of fluid nutriment; and these they ornament with a profusion of blossoms, having brilliant colours. They usually expand in the night, and after a few hours' exposure to the sun, they perish. A few species (belonging to the genus *Helianthemum*) are natives of this country; and others, introduced from the South of Europe, are cultivated as evergreen bushes in shrubberies, or are employed to ornament rough banks and masses of rock-work, over which they trail with great beauty. In the general characters of their flowers, they may be regarded as intermediate between the Papaveraceæ, and the Violaceæ—the order to be next described. The sepals of the calyx are five; but these do not exactly form a single regular whorl, as two arise somewhat lower than the others, and are somewhat external to them. The corolla usually consists of five petals, which, from the manner in which they are packed within the bud, have a crumpled appearance when the flower unfolds; they fall off at an early period of flowering, whilst the calyx remains as a protection to the seed-vessel. The stamens are hypogynous, and indefinite in number; and they are usually much shorter than the petals. The ovary is superior, and is either one-celled with parietal placentæ, or is divided into five or ten cells by partitions radiating towards a centre. There is never more than one style, and this terminates in a simple expanded stigma. The fruit is a

capsule, usually separating into five or ten valves; along the middle of each of which there is a placenta, or a partial dissepiment. The seeds contain a small quantity of albumen; and the embryo is very curiously coiled up. All the species, in common with those native to Britain, belong to the Linnæan class POLYANDRIA, order *Monogynia.*

537. This tribe evidently resembles the Poppies, in the transitory character of the flower, as also in the crumpling of the petals; but particularly in having a large number of hypogynous stamens, and a seed-vessel partially divided, with numerous seeds arising from parietal placentæ.—But, on the other hand, they are separated by many points of difference; for the calyx of the Papaveraceæ is formed of only two pieces which soon fall off, whilst that of the Cistaceæ is composed of five sepals, and is persistent; the former possesses a milky juice, which the latter do not afford; in the former, there is a large separate albumen, whilst in the latter there is a small one.—Further, they are separated by a peculiar character which is of no small physiological importance. The *foramen* of the seed,—the aperture by which the fertilising influence is received, and the radicle afterwards makes its way out (§. 436),—is usually situated at the end nearest the placenta; and the pollen-tubes pass into it, by insinuating themselves along the cord which connects the ovule to it. In the Cistaceæ, however, the foramen is situated at the point of the seed; and the manner in which the pollen-tubes find their way into it is very curious. When they have reached the top of the ovarium, instead of passing down its sides to the placentæ, they separate themselves into bundles, of which one directly enters each cell of the seed-vessel, and spreads through it like a fine cobweb, lengthening until it reaches the apertures of the ovules.—The plants of this tribe chiefly abound in the South of Europe and the North of Africa, being scarcely known in Asia and America. They are not known to possess any peculiar properties; a gum-resin termed Labdanum, which was once used in medicine, is obtained from one species. They are all low shrubs or herbaceous plants.

538. The next tribe which will be noticed is also a small one,

mostly composed of still humbler plants, but containing some well-known species of general interest. This is the order VIOLACEÆ, or *Violet* tribe, the largest of the British species of which is the common *Pansy* or *Heartsease;* this will be convenient, therefore, to describe in illustration. On looking at the leaves, they will be found to be rather small, and to arise by long stalks, at the base of which are a pair of large stipules; these are very characteristic of the order. The flower consists of five narrow sepals, some much larger than the rest; which are usually prolonged in a curious manner at the base. The corolla consists of five petals, of which, in the Pansy and most other species, two stand nearly erect, so as to appear above the others. These two in the Pansy are differently-coloured; and a third, standing in front of them, has a short horn or spur at its base. The stamens are also five in number, and generally of irregular form, possessing no proper filament, but having a membranous expansion in place of it, which is elongated above the anthers; two of them, in the Pansy, have long projections, which are hidden in the horn of the petal. The anthers are often coherent to each other, and lie close upon the ovary. The ovarium is superior, and contains but one cell; it possesses, however, three parietal placentæ (Fig. 84, §. 434), to which many ovules are usually attached. There is but a single style; and the stigma is covered with a kind of hood, so that access can only be gained to it by an aperture on one side. For this singular conformation, no use has been assigned. When the fruit is ripe, it is still surrounded by the calyx; it is an oblong shining case, which splits into three valves, having the seeds adherent to the middle of each. The Heartsease of the gardens has been greatly improved in its beauty as a flower by cultivation; and a number of varieties, differing chiefly in their colours, are known to florists. The common Sweet Violet has no rival among flowers, if we seek for delicate fragrance; and this is not improved by cultivation.

539. This order is readily known from all other hypogynous Exogens, by its persistent calyx, its irregular flowers, and by the three narrow parietal placentæ situated in the middle of the

same number of valves. In the persistence of the calyx, the prevalence of the number 5 in the flowers, and in the slight division of the ovary, it is evidently allied to the Cistaceæ. Of the plants contained in it, few are natives of Asia; and those which inhabit South America differ from the rest, in being shrubby instead of herbaceous. The roots of all the Violaceæ appear to be more or less emetic; and those of South America are particularly so, and are used in medicine under the same circumstances as those in which Ipecacuanha is employed in this country.

540. Nearly allied to the violets is the little order DROSERACEÆ, or *Sun-dew* tribe; so named from the peculiar appearance (presently to be described) of the British species, by which it may be illustrated. The little *Sun-dew* is a plant whose home is in fens and morasses, where it takes possession of the small hillocks elevated above the surrounding waters; and it cannot be made to flourish, if transplanted into any other situation. The leaves of this little plant are the most conspicuous part of it, whilst the fructification is the least so. When spread out, they form small concave disks, covered with long shining red hairs, that secrete from their point a clear fluid, which gives the leaves the appearance of being covered with dew-drops. This secretion is most abundant when the sun is at its highest, whilst real dew is only seen on leaves in the early morning; and it is from this circumstance, as well as from the peculiar sparkling appearance of the surface, that the name of the plant is derived. The hairs, when examined with a high magnifying power, are extremely beautiful microscopic objects; they are seen to consist of an immense number of minute cells, arranged with great regularity; and if illuminated by a strong reflected light, the rays from below being cut off, they exhibit a most gorgeous variety of brilliant colours. The fluid secreted from their points has a slightly acrid taste, and it appears to retain insects which settle upon it. The hairs themselves exhibit a considerable degree of irritability; slowly curving inwards, and entrapping any unfortunate victim that may have come within their reach. This irritability is manifested to a much greater degree in the

Dionæa, (§. 246) which is an American species of this order: and it is common, in a greater or less degree, to the other known species of it. The organs of fructification are nearly allied to those of the Violaceæ. The flower is regular, however; the stamens have the usual form, and are sometimes double or triple the number of the petals; and the ovary bears from three to five styles. The order is also peculiar as to the manner in which its leaves and flowers are folded together before their expansion. Instead of being simply compressed into buds, they are coiled in a spiral; so that, when unfolding, the leaf-stalks and flower-stalks somewhat resemble a shepherd's crook. This form of development is the same as may be readily observed in the unfolding leaves of the young Fern. (See the highest leaves in Fig. 3, §. 23).

541. Passing over several Orders which contain but few species, and these of little general interest, we stop for a short time at one which contains many well-known British plants,—the CARYOPHYLLEÆ, or *Chickweed* tribe. These are natives principally of the temperate and frigid parts of the world, where they inhabit mountains, hedges, and waste places. Those which are found within the tropics are usually natives of elevated or mountainous tracts, almost always reaching the limits of eternal snow, where many of them exclusively vegetate. The greater part of them are regarded as mere weeds; but some of them are greatly improved by cultivation, and become handsome garden plants, which are greatly valued. Such are the Clove-Pinks, Carnations, and Picotees, which are all varieties of one species, the *Dianthus Caryophyllus*, that naturally grows about old walls, especially on the ruins of ancient castles. The structure of the flower may be best understood from some of the larger species, such as the common Pink; taking care, however, not to choose a double one. It is interesting to remark that whilst in this plant, the leaves—being long and narrow, with only a single vein running from one end to the other—do not afford any characters by which it might be known as an Exogen, the petals (which are but differently-developed leaves) have a beautiful system of veins, which are evidently reticulated. The stems are

very much swollen at the points from which the leaves arise: and this is a character which marks the whole order. The calyx is a tube composed of five sepals united together, and separated only at their points. Five petals arise from within them, of which the lower ends are very narrow, whilst the upper ends are greatly expanded, and are irregularly jagged at their borders. The stamens are ten in number, with short stalks. The ovary is one-celled; and in its centre is a column, round which a great many ovules are clustered. In the Pink there are two styles, each terminating gradually in a narrow fringed stigma; in other species there are three, and in others five styles. The first becomes a dry *capsule*, opening from the point by four valves. The structure of the seed is variable.

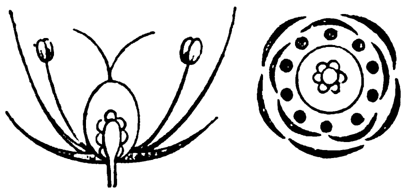

Fig. 141.—Diagram of the Flower of Caryophylleæ. A, vertical section. B, horizontal section.

542. This order may be distinguished from all other polypetalous Exogens, by the possession of opposite undivided leaves without stipules, and by the tumefaction of the stem at the nodes; it is further separated from others having the same number of stamens, by the structure of the ovarium. This is one of the orders in which a certain amount of variation occurs in the number of the parts of the flower; which are sometimes arranged on the *quaternary* type, or in *fours*,—sometimes on the *quinary*, or in *fives*. The stamens are almost invariably twice as numerous as the petals. Hence, while most species of this order are comprehended in the Linnæan class Decandria, a few fall into Octandria; they of course belong to the orders *Digynia*, *Trigynia*, and *Pentagynia*, according to the number of their styles. The order is divided, in the natural arrangement, according to the adhesion or separation of the sepals of the calyx. The division in which the calyx is tubular contains, with the Pink, the *Silene* or Catchfly, named from often secreting a viscid matter in which flies are caught; the Cockle (*Agrostemma*),

which is often a very troublesome weed in corn-fields; the Ragged Robin (*Lychnis flos-cuculi*), frequent in meadows; and the Bachelors' Buttons (*L. dioica*), which is an exception to the general rule, in being diœcious. The second division, which has the sepals distinct, contains the numerous species of common Chickweed or Stitchwort (*Stellaria*), the Mouse-ear Chickweed (*Cerastium*), of which some species are peculiar to Alpine districts, whilst another affects moist situations; and the Sandwort (*Arenaria*), so named from the character of the soil in which most of its species flourish best, though some of them are only found in rocky and mountainous places. In regard to the properties of this order there is little to be said. The species belonging to it are in general both insipid and inodorous. Many of the wild species seem to be sought as favourite articles of food by small animals, and some have been cultivated as fodder for cows, the quantity of whose milk they are said to increase.

543. The succeeding order is one which contains but a small number of genera; but these are distributed over the whole world, and afford a product of the greatest importance to Man. This is the order LINACEÆ, or *Flax* tribe, which was once associated with the last order, but differs from it in so many important characters, that it is separated with complete propriety. In the first place, the stems of the *Flax* are not swollen at the nodes, and the leaves are usually not opposite. The sepals of the calyx, which are always distinct, are not arranged in a continuous whorl; but two are external, partly overlapping the others, which are internal; this arrangement, which is termed *imbricated*, is quite different from that which we have seen in the Chickweed tribe. The two outer sepals are marked * in the diagram. The whole number is generally five, sometimes four. The petals are always equal in number to the sepals. The

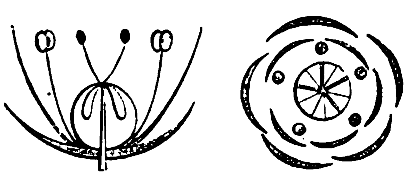

FIG. 142.—DIAGRAM OF THE PARTS OF THE FLOWER IN THE ORDER LINACEÆ.

stamens are equal in number to the petals, and are united at the base into a downy cup; the edge of this exhibits, between the stamens, a corresponding number of little teeth, which are the abortive rudiments of another whorl (§. 465). Within these is the ovary, which appears to contain ten cells, in each of which is a single pendulous ovule; but the number of real cells is only five (in some species four), of which each is partly divided into two by an imperfect partition, extending inwards from its outer wall. Such a partition is termed a *spurious* dissepiment. The ovary bears five (or four) styles and stigmas; and finally the seed-vessel splits into ten valves. By all these strongly-marked differences, the real affinity of the Linaceæ to the Caryophylleæ is rendered very small.

544. There is scarcely any plant which is less affected than the common Flax, by differences of soil and climate; and accordingly one species, with all its characteristics unaltered, flourishes in the cold as well as the temperate regions of Europe, in North and South America, in Africa, and in Asia. There are few plants which are made subservient to so great a variety of uses; from which circumstance it is, that this species of *Linum* has received its specific name *usitatissimum*, which means "in most common use." It is from the woody fibre of its stem, that all the *thread* is obtained, which has been from very early ages employed in making *linen* fabrics (the name of which is derived from that of the genus); and it is now used for this purpose to a greater extent than ever, in spite of the degree in which it has been superseded by cotton. The seeds contain a large quantity of oil, which is readily obtained from them by pressure, and is known under the name of linseed oil (§. 371); and the oil-cake which is left is an excellent food for cattle. The seed-coats also contain a large quantity of mucilage; so that an infusion of the seeds, known as linseed-tea, is frequently of great utility as an external soothing application, and is sometimes a very useful internal remedy. Further, the seeds, when ground into a meal, form the most advantageous material for large poultices; and an enormous quantity is consumed for this purpose, especially in hospitals. The plant, however, is not much cultivated in Britain,

notwithstanding various inducements held out by the legislature; for its crops are of inferior value to corn; and it is found to render the soil more unfit for the subsequent growth of other crops, than does almost any other cultivated vegetable. The principal supplies required for British manufacture are drawn from Russia, the Netherlands, and Prussia; some is also brought from France and Egypt, and even from New South Wales. The annual imports vary from 40,000 to 75,000 tons of flax; and about two million bushels of linseed. Flax is grown, however, in Lincolnshire, Somersetshire, and Yorkshire, to a small extent; it is more cultivated in Scotland; and nearly all that is required for the extensive linen factories of Ireland is the produce of that country.

545. The common Flax-plant is an annual, which shoots forth slender upright hollow stalks, about the thickness of a crow-quill. These are surrounded by a fibrous bark or rind, containing woody bundles intermixed with cellular tissue. When the plant has attained the length of about 2½ or 3 feet, it divides into slender flower-stalks; but there is a considerable difference in the dimensions of the stem, according to the soil, season, &c. This difference governs the treatment of the plant; for, if the stem be short and disposed to branch, the plant is considered more valuable for its seed than for its fibrous bark, and is not gathered until its seeds are fully matured; whilst if the stem grows long and straight, all care of the seed becomes a secondary consideration, and the flax is pulled at the most favourable period for obtaining good fibres, which is a little after the withering of the blossom, before the seeds are quite ripe. The Dutch are accustomed to lay up the plants in stacks, as soon as they have pulled them; experience having shown that, in most instances, seed will ripen after the parent-plant has been pulled, provided that it be not detached from it, being supplied by the sap which it contains; and thus both good flax and seeds may be obtained from the same crop. The stems are freed from the leaves and seed-vessels by a process called *rippling;* which means passing them through a sort of comb with long teeth, by which these parts are torn off. The flax is then placed in water, to

dissolve the gummy sap, by which the bark adheres to the woody portion of the stalk, and to favour the decomposition of the soft cellular tissue by which the woody bundles are held together. This process, which is called *water-retting*, renders the water offensive, and is said to be unhealthy to the neighbourhood; and an act preventing its being carried on in any common stream or pond, is in force in this country. The length of time required varies from about 10 to 15 days, according to the state of the flax, the temperature of the water, &c. It has been recommended as a much better method, to steep the flax in hot water for a short time, with soft soap. The water-retting of fine flax, for the manufacture of the most delicate cambrics and muslins, is attended to with great care; it is particularly necessary that there should be a constant renewal of the water, as the fibres will otherwise acquire a dark tinge, of which it will be almost impossible to get rid by bleaching. The fibrous bundles are then separated from the rest of the tissue, by being passed between two surfaces, one of which has grooves, into which enter projecting ridges on the other. In former times, and in some countries at the present, a very simple machine is used for this purpose, termed a *break;* this consists of two long blocks, cut in the manner just described, united by a hinge at one end; the lower one being supported, the upper is lifted at the other end by the right hand, and the stems are drawn with the left between the two jaws of the break, which are made to close together forcibly several times, so as to bruise the stems and separate their parts from each other, without breaking the fibres. After this another operation is required, to separate the smaller particles of bruised refuse from the flax; this is termed *scutching*. These two operations are now usually performed together by a machine, principally consisting of three cylinders with ridges and indentations that work into each other; and between these the flax is passed. After this, the flax is *heckled*, by drawing the bundles through a frame studded with rows of sharp pins; this effectually frees it from all extraneous matter, and presents a series of smooth distinct filaments. It is then ready for the spinner. The finer kinds of flax, however, are prepared in a more

delicate manner; being merely scraped or cleansed with a blunt knife on a soft skin of leather, and afterwards dressed with a kind of brush. Machine-spinning has now almost superseded hand-spinning in this country; but the finest thread can be produced only by the latter process. By machinery a thread measuring 12,000 yards has been spun from one pound of flax; but by hand-spinning a thread of three times that length has been produced from the same weight.

546. The only other species of this order, which is cultivated for the same purpose, is the Siberian perennial flax. This is a much taller plant, having coarser fibres; these are found to be very strong, but not so white or fine as those obtained from the common flax. They serve very well, however, for the manufacture of coarse fabrics; and there is this advantage attending the cultivation of them,—that from the same root, a succession of stalks will be developed for many years; so that they require no further attention, than to be kept free from weeds. The juices of all the plants of this order seem to have a purgative quality; this is very slight in the common Flax, but is greater in the common *Linum catharticum* or Purging-flax of this country, as well as in some foreign species.

Order MALVACEÆ, *or Mallow Tribe.*

547. Almost every child is familiar with the *cheeses* that he finds among the hedges; and there is not a civilised human being who does not make great use of *cotton* fabrics; yet few, save professed Botanists, are aware how close a relation there is, between the humble neglected plant that bears the former, and the cherished exotic shrub to which we are indebted for the latter. They both belong to the same order, which is marked by characters that readily distinguish it, and which may be explained from the common British Mallows, as well as from any other of the more highly-prized species. Of the former there are two kinds, one bearing small pink blossoms, the other large purple ones, which are among our handsomest wild flowers. The latter, which may be best chosen for examination, grows

two or even three feet high, in places where it is not cropped by cattle; its stem is covered with longish hairs, which frequently spring in stellate (star-shaped) clusters; its leaves are roundish, slightly divided at their edges, and possess small scale-like stipules at the base of their petioles. The sepals are five, and are placed in a uniform whorl; they are partly adherent; and on the exterior they have three bracts, so arranged as almost to resemble an additional calyx. The petals are also five; previously to their expansion they are folded together in a very curiously-contorted manner. The stamens are numerous; and their filaments adhere at their lower part, so as to form a tube which embraces the pistil. This structure is exactly what is termed, in the language of the Linnæan classification, *monadelphous;* and the whole of this order, therefore, belongs to the Linnæan class MONADELPHIA. The anthers only possess one lobe, which opens transversely. The pistil is composed of several united carpels, each of which has its own style arising from its summit; the styles, like the stamens, are united at their lower part into a tube. The seed-vessel is divided by complete partitions into numerous cells, each of which contains one or two ovules; and when cut across in its unripe condition, the ovarium exhibits a very beautiful aspect, from the regularity of the arrangement of its contents. When ripe the carpels readily separate. All the characters now enumerated, with the exception of the number of sepals and petals, which varies from three to five in each whorl, are common to nearly the whole order.

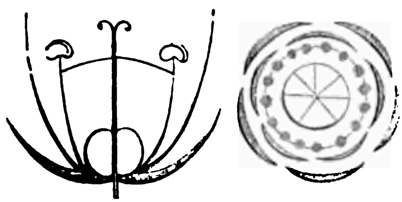
FIG. 143.—DIAGRAM OF THE FLOWER OF MALVACEÆ.

548. The British species are not numerous; they consist of four of the genus *Malva*, or ordinary Mallow, two of the *Althæa* or Marsh-mallow, and one of the *Lavatera* or Tree-mallow, so called from its higher growth. These are remarkable for little else than the quantity of thick transparent mucilage, which

almost all the green parts yield; and on this account they are thought to afford useful remedies in some pectoral complaints. They do not possess, however, any active properties. It is between the tropics, that the most remarkable species of Malvaceæ abound; and this seems to be the natural habitation of the Order, since the proportional nnmber of species belonging to it in any country, diminishes rapidly as we pass from the Equator to the Poles. The showy Hollyhocks, now naturalised in our gardens, are species of Malvaceæ introduced from a warmer climate. The genus *Hibiscus* is remarkable for the striking aspect of its flowers, which are much cultivated in hot-houses in this country; their stems contain strong and tough fibres, which have been used as a substitute for flax and hemp in making cordage. (It is said that whips, formerly employed by slave-drivers in the West Indies, were made of the plaited fibres of this plant). The unripe fruit of one species of Hibiscus, known in the East and West Indies under the name of Ochro (in some places Gobbo), is used, on account of the abundance of its mucilage, to thicken soups. Other species of this genus contain a powerful colouring principle, which gives a black stain to anything which it touches; and the leaves of a species of Althæa are said to yield a blue colour not much inferior to indigo.

549. Of all the genera of this order, however, there is none so important to man as that which yields Cotton; and it may be questioned if there is any other single tribe, except the Grasses, with which he would now find it more difficult to dispense. Cotton is derived from several species of *Gossypium*, which are cultivated in both the Old and New World; of no part of Europe, however, are any of these species natives, though cotton has been cultivated in the southern parts of Spain and Italy. There is much uncertainty as to the real number of species; as the genus is one in which there is a great tendency to the production of varieties. It is desirable, however, that their respective characters should be well ascertained; since the differences in their produce make the knowledge of them of great importance to the cotton-planter, as this varies greatly both in quantity and quality. Some yield their downy harvest twice

in the year; others only once. Some bear cotton of a long and delicate fibre, and of a beautiful whiteness; whilst the fibres of others are short, coarse, and of a bad colour. These differences are strongly marked in the cotton imported from different countries; thus the American cotton fetches a much higher price in the market than the Indian; and, though it cannot be questioned that the soil, climate, and care in gathering, have a considerable influence on the goodness of the article, yet it is also as certain that great improvements might be effected, by replacing inferior species or varieties by others of more value. This is now being attempted in India.

550. The fibres of Cotton are obtained from the seed-vessel, in which they are packed round the seeds; and no further trouble is necessary to obtain them, than to withdraw them when the capsule bursts. This should be done as early as possible: since exposure to the sun gives a yellow tinge to the cotton. These fibres do not consist, like those of flax, of woody tubes; but they are composed of cellular tissue; and they are consequently much weaker in proportion to their diameter. The greatest difficulty in the gathering of cotton, consists in the separation of its fibres from the seeds they enclose, to which they sometimes adhere with great tenacity; the firmness of this adhesion varies in different species; and *that* is to be preferred, therefore, in which the cotton is most readily freed. In the greater part of India, the use of machinery for this purpose is unknown; and the cotton is cleansed by hand; in America, however, large machines are employed, which accomplish it very rapidly and effectually. A species of Gossypium cultivated in China is remarkable as having naturally a coloured fibre; it is from this that the *Nankeen* cotton stuffs are made, which were at one time commonly worn in this country, and the name of which was derived from that of the place where alone they were manufactured.

551. Notwithstanding the enormous amount of raw Cotton now imported into this country for the supply of its manufactories, the employment of it in Britain, to any considerable extent, is comparatively recent. In the 17th century, the

trifling supply required was obtained wholly from Smyrna and Cyprus. In the year 1786, about 20 million pounds were imported; of which about a quarter was from Smyrna, &c., another quarter from the British West Indies, and the remainder from other colonies. Shortly after that period, when machines for spinning cotton-yarn were devised by Arkwright and others, the annual consumption of cotton increased six-fold, and it has been progressively augmenting ever since. From all quarters of the world does the raw material now flow in upon us; and it is converted, with an expedition scarcely credible, into textures, of which a large part are re-conveyed to the countries which originally furnished it. In the year 1838, the quantity imported was upwards of 500 millions of pounds; whilst of this there was exported in the form of woven stuffs nearly 700 million yards, and of twist and yarn about 115 million pounds; the value of which, together with that of the cotton hosiery and small wares exported, would amount to about twenty-four millions sterling. When machinery was first introduced, it was made capable of spinning a pound of cotton into yarn 160 miles long; and a much greater degree of fineness may now be attained. The hand-spinners and weavers in India far outdo machinery in the delicacy of their fabrics, some of their muslins being expressively termed "woven air;" but so great is the saving effected by machinery, in the production of all cotton fabrics but such as these, that a large proportion of those used in India are exported from Britain; it being a saving of expense to cause the materials thus to undergo the double voyage, although labour is so extremely cheap in India.

552. Nearly allied to the order Malvaceæ, which contains few save herbaceous or shrubby plants, is the order BOMBACEÆ, or Silk-cotton tribe, none of which are herbaceous, whilst some species are amongst the most remarkable examples of arboreal vegetation, such as the celebrated *Baobab* trees of Senegal. (§. 129). One of the trunks of this species has been found to be of the enormous girth of from 90 to 100 feet; the spread of the branches and roots is enormous; one main root, uncovered by a stream, having been traced to 100 feet from the stem, and pro-

bably extending much further. The height of the trunks, however, does not bear the usual proportion to their thickness, being in general but little more than their diameter. In the interior parts of Africa, at a distance from rivers, the trunks of these trees are converted by the natives into tanks, their heads being cut off, and their immense bodies hollowed out for the reception of water, which in consequence of the softness and lightness of the wood, is not a difficult task. On the eastern coast of Africa, this tree is very liable to be attacked by fungi, which prey upon its heart-wood, and, without changing its general appearance, destroy the life of the tree, and render the timber very soft. Such trees are hollowed out by the natives as burial-places for the bodies of those who are supposed to hold communion with evil spirits; and these, being suspended in the chambers thus constructed, become dry, and are well preserved like mummies. The bark of the Baobab yields a coarse thread, of which ropes and cloths are made; and its fruit contains a mealy pulp around the seeds, which forms a wholesome and agreeable article of food.

553. The species yielding the Silk-Cotton of South America is also a large tree having a light wood; this is frequently employed for making canoes, and a single trunk has been known thus to hold 150 men, or twenty-five tons of sugar. The tree derives its name (*Bombax*, resembling that of the Silkworm), from the peculiarly silky character of the hairs, which surround the seeds, in the same manner as the wool of the Cotton. This wool is commonly used to stuff cushions and beds; and lint and a sort of felt have been made from it; but it cannot be spun into threads, in consequence, it is believed, of the absence of the minute roughnesses, which exist upon

FIG. 144.—BOMBAX.

the surface of the true Cotton fibres, and which are very important in binding them together. The difference between the Bombaceæ and the Malvaceæ, in any other respect than their size, is not great. The calyx of the former is not exactly valvate; the tube formed by the adhesion of the stamens is cleft at its upper part into five divisions; and the anthers, which, like those of the Malvaceæ, are one-celled, burst longitudinally instead of transversely. They resemble Malvaceæ also in the mucilaginous character of their juices, and in the entire absence of any deleterious properties. They are all natives of tropical climates.

554. Another order nearly allied to the Malvaceæ, is that of BROMACEÆ (the Byttneriaceæ of De Candolle) or *Cacao* tribe. They are usually shrubs or trees, which are, like those of the last order, confined to tropical regions and countries bordering on them. They have no very obvious differences from the Malvaceæ, except that the petals are often absent, and that the anthers are two-celled, bursting longitudinally. The stamens are variously united, but usually form a single tube; not unfrequently many of them are abortive; and, as in the Cacao itself, they assume the form of narrow petals intermediate between the true stamens. The carpels are less numerous than those of the Malvaceæ, varying from three to five; and the number of ovules in each cell is usually much greater. Like the Malvaceæ, these plants are remarkable for the quantity of mucilage they contain; and it is from one species that the Gum Tragacanth, so much used in the arts (§. 380), is obtained. In a few species, the juices possess a slight acridity; and in others some astringency.

555. The order is chiefly interesting on account of the importance of the genus *Theobroma Cacao*, in yielding the material of a wholesome and nutritious beverage, the occasional use of which in this country gives but a slight idea of the large quantity consumed in many others. It is a little curious that, whilst the generic name, signifying "food for the gods" was given to it by Linnæus, on account of his high estimation of its qualities, a traveller of the sixteenth century declared that chocolate was a drink "fitter for a pig than for a man." The Cacao tree rises

usually to the height of about 20 feet, though sometimes it attains an elevation of 30 or 40 feet; its leaves are large, oblong, and pointed; whilst its flowers are small, and of a pale red. The calyx consists of five sepals of a deep red; and within these is a corolla formed of five petals, the form of which is peculiar. They are broad and channelled into a sort of gutter at their lower part, in the middle they are extremely narrowed; and they expand again towards the summit, at which they adhere. The stamens form a tube, on the upper end of which the five that bear anthers alternate with the other five that have a narrow petalline form; and the latter, in the complete flower, are seen projecting above the ring formed by the adhesion of the top of the petals. The pistil is formed on the same general plan as in the Malvaceæ, consisting of five adherent carpels, each of which has its own style and separate stigma; but the ovules are numerous, varying from 20 to 100 in the whole capsule.

FIG. 145.—FLOWER OF THEOBROMA CACAO.

1, Complete flower; *a, a*, the petals; *b, b*, the petal-like stamens; 2, the tube formed by the adhesion of the stamens, cut open, showing the five true stamens alternating with five abortive; 3, pistil, with a single style composed of five adherent carpels, and surmounted by five separate stigmas.

556. The fruit, when ripe, is a long oval, of which the surface is covered with rounded eminences, and is marked by ten furrows; its interior cavity is simple, in consequence of the obliteration of the original partitions; and the seeds are grouped round a central column. They are imbedded in a sort of mealy pulp, which, although sweetish, has a disagreeable flavour. This pulp is sometimes removed from the seeds by washing, after which they are dried in the sun; and sometimes, in order to get rid of it, they are buried in the soil, until it is detached by decomposition. The seeds are then prepared by roasting, after which their hard husks are easily detached; and the fleshy interior is beaten up into a smooth paste, which is afterwards

dried. Chocolate differs from cacao, simply in the addition of various spices and flavouring ingredients. It is much more employed in France than in England, and is commonly drunk for breakfast in Spain. In Mexico it is considered an article of prime necessity; and it was extensively cultivated there, at the time of the Spanish invasion of South America. Humboldt, the celebrated traveller, remarks, that it is by chocolate and maize-flour, that man has been enabled to penetrate the vast uninhabited forests of central America, and to gain access to the stupendous table lands of the Andes. The seeds were employed as coins, in order to express values below sixpence, which was that of the smallest metal coin, six of them being about equivalent to a halfpenny; and this use of them is still partially continued. A kind of buttery substance may be extracted from the seeds of the Cacao, which is said to have a very bland and agreeable flavour, and to serve as an excellent emollient application to the skin; whence it is highly prized, in some countries, as an ingredient in ointments and cosmetics. It was estimated that, in 1806, about 23 million pounds of Cacao were imported into Europe from South America, Mexico, and the West Indian islands; of this quantity, the greater part was consumed in Spain. The quantity consumed in Britain in the year 1831 was not more than half a million of pounds, but in that year the duty was lowered from sixpence to twopence a pound; the consumption immediately doubled, and it is now two millions of pounds annually. A large quantity is employed in the British navy and merchant-service, as a partial or entire substitute for ardent spirits; and it may be expected that the rapidly-increasing disuse of the latter most injurious liquors, will occasion a still further demand for this wholesome and nutritious article.

FIG. 146.—FRUIT OR CAPSULE OF CACAO-PLANT, containing the seeds or nuts.

557. The order TILIACEÆ, or *Linden* tribe, is also nearly allied to Malvaceæ. The principal part of this order consists of

herbaceous plants, with handsome flowers, which abound within the tropics; some species, however, are lofty trees; and these, contrary to the general rule, are natives of temperate regions. Three species of Linden or Lime-tree are found in Britain; of which the largest and best known was probably not originally a native of this country. This last sometimes grows to a great size; and its wood, being light, soft, smooth, close-grained, and not liable to be worm-eaten, is valued by carvers for ornamental works, and also forms one of the best kinds of charcoal for the manufacture of gunpowder. Its flowers are very fragrant, and are a favourite resort of bees, who obtain from them not only honey but a large supply of pollen, which they store up for the nourishment of their young; and if a hive of bees is at no great distance from a grove of limes, it may be known when these are in flower, by the large number of bees that will return laden with little pellets of the bright yellow pollen which these blossoms furnish. There are perhaps no trees which form so beautiful an avenue,—the peculiar mode in which the branches arise from the stem and meet above, giving them very much the aspect of the Gothic columns and arches of a cathedral; and when the lover of Nature walks beneath their luxuriant foliage, "at dewy eve distilling odours," he feels them to constitute a fit temple for the worship of Nature's God. The characters by which this order is distinguished are such as to show its near alliance with the Malvaceæ. The calyx consists of four or five valvular sepals; and the corolla of an equal number of petals, which are rarely wanting. The stamens are indefinite in number, and not united into a tube; and the anthers are two-celled, bursting longitudinally. The pistil is formed of four to ten united carpels, having a single style, and stigmata equal in number to the carpels, as in the Bromaceæ. The partitions are permanent, so as to divide the fruit into cells. They are at once known from the Malvaceæ and two succeeding orders, by the non-adhesion of the stamens; and from the Malvaceæ and Bombaceæ by their two-celled anthers. In their general properties, the Tiliaceæ resemble the Malvaceæ; they are quite harmless, and contain a considerable quantity of mucilage. The sap of the Lime abounds

in saccharine matter, from which a good sugar has been extracted, and a pleasant wine obtained by fermentation; and its nuts are said to possess, when roasted, something of the flavour of chocolate. The bark of most species of the order is tough and strong, and easily separable into layers; and from these, mats, baskets, and cords are made in many countries.

558. The small order DIPTEROCARPEÆ, nearly allied to this, is worthy of notice, on account of its containing the Camphor-tree of Sumatra, from which our chief supplies of camphor (§. 383) will probably hereafter be obtained, though they are at present derived mostly from a species of Laurel. This product is stored up in the former, in receptacles (§. 98) sometimes a foot and a half long; but the tree must be deeply cut into, in order to open these. Some other trees of this group (which is entirely confined to tropical climates) afford small quantities of resin; it is from one of these that the Piney tallow (§. 382), and from another that Copal (§. 377), is obtained.

559. The next order to be particularly noticed is one of special interest, from its furnishing a product which, without being in the least nutritious, is considered by the Englishman, in almost all ranks, as one of the most indispensable articles of his diet. This order is that of CAMELLIACEÆ, the *Camellia* tribe, well known to the Horticulturist for the beauty of its flowers; and it is from various species included in it that *Tea* is obtained.

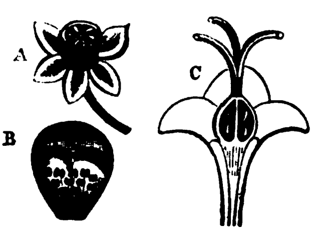

FIG. 147.—STRUCTURE OF FLOWER OF TEA PLANT. A, calyx, with ovarium cut across. B, petal, with bundle of stamens adherent to it. C, vertical section of ovarium, with the three styles.

The *Camellia*, now cultivated in most gardens, will afford a good illustration of the characters of the order, which approach those of the succeeding one. The calyx is composed of from 5 to 7 sepals, unequal in size, of rather tough consistence, and in some degree overlapping each other. The petals are from 5 to 9, also occasionally imbricated, and sometimes slightly adherent at the base. The number of stamens is indefinite; and

they are generally united at the base into one or more bundles. The ovarium is formed of from 3 to 6 carpels, more or less united, with separate styles; each cell originally contains several ovules. In the ripe capsule, there are only three cells, each containing but one seed (the other ovules not having been developed); and this is large, with fleshy cotyledons that contain a large quantity of oil, and is destitute of albumen. The Camelliæ are celebrated for the great beauty of their foliage, and the splendid colours of their blossoms, which vary through every shade and mixture of red and white. The C. Japonica is a lofty tree in its native country; and even in our conservatories it sometimes reaches a considerable size. The leaves of some species of Camellia have been used as Tea; but this is properly derived from the genus *Thea*.

560. Notwithstanding the many different kinds of Tea exported from China, it has now been ascertained that they are

FIG. 148.—TEA PLANT.

all the produce of two species; one of them called *Thea viridis*, from its having been supposed to be the plant employed in making *green* tea; the other called *Thea bohea*, having been in

like manner considered the *black* tea plant. It is now quite certain, however, that *both* kinds of tea may be produced from *either* species, the chief difference between these articles being dependent upon the mode in which they are prepared. The black and green teas of the northern district of China, from which the foreign markets are chiefly supplied, are the produce of the *Thea viridis*; whilst the teas of both kinds mauufactnred in the neighbourhood of Canton, are obtained from the *Thea bohea*. By some botanists these two species are regarded as varieties of the same; each of them is liable to undergo numerous variations, under the influence of soil, climate, exposure, &c.; and to these differences, in combination with diversities in the time of gathering the leaves and in the mode of preparing them, we are to ascribe the great number of varieties in the product. In the preparation of *black* tea, the leaves are exposed to air after being picked, but are kept cool until they begin to emit a slight degree of fragrance, apparently in consequence of having undergone an incipient fermentation, like that which produces the aroma of hay. They are then roasted at a moderate heat over the fire, until they give out a fragrant smell and become quite soft and flaccid; after which they are rolled under pressure, again roasted and rolled until the juices are pressed out, and finally dried and twisted between the fingers. On the other hand, in order to make *green* tea, the leaves are roasted as soon as possible after gathering; and they are exposed in this process to a much higher temperature than that employed for black tea. They are then spread out to cool, and afterwards again roasted at a lower temperature. When cooled a second time, they are of a dark olive colour. In the third roasting, which is the final drying, the heat is again diminished; and it is then that the colour of the leaves changes to that bluish tint, resembling the bloom of fruit, which gives to this tea its peculiar appearance. The peculiar properties of *green* tea are obviously due to a chemical change, brought about by the action of a high temperature on the juices of the leaves; and it is only in the inferior kinds that any artificial colouring

ingredients are employed. The Tea plant is cultivated in China from about the 27th to the 33d degree of north latitude; but it will flourish in regions more distant from the Equator if the climate be mild and equable. It has been found growing wild over extensive tracts in Assam, at the north-east of Hindostan; and attempts are now being made to cultivate it there on a large scale

561. The history of commerce does not furnish any parallel to the circumstances which have attended the introduction of Tea into Great Britain. The leaves are said to have been first employed by the Chinese to cover the taste of their water, which is in many districts brackish and unpalatable; and the infusion being found to be pleasant in its flavour, and productive of an agreeable excitement, the practice of drinking it gradually extended in those places where the water was good, and at length was introduced into Europe. The leaf was first imported by the Dutch East India Company in the early part of the seventeenth century; but it does not appear to have found its way to England until about the year 1650. The first historical notice of it is in an Act of Parliament of the year 1660, in which it was enumerated as one of the beverages sold in coffee-houses, on which a duty was to be laid. That it was not then a common drink, is evident from an entry in the private Journal of Mr. Pepys, Secretary to the Admiralty, who says, Sept. 25, 1661, "I sent for a cup of tea (a China drink), of which I had never drunk before." In 1664, the British East India Company sent *two pounds* of tea as a present to the King. In 1667 they issued their first order to import tea, directed to their agent at Bantam, to the effect that he should send home 100lbs. of the best tea he could get. Since then, the consumption has gone on regularly increasing. In 1734, the quantity imported was about 632,000lbs; in 1768, it was nearly seven million pounds; in 1800, it was twenty millions; and during the last four years of the East India Company's charter, the average quantity imported was 31½ millions. Since the abolition of the monopoly, and the consequent reduction of prices, the consumption has increased still more rapidly; the amount imported having in some years nearly reached 50 million pounds, of which above 44 million pounds were consumed in Great Britain and Ireland,—a quantity much

exceeding that consumed in all the rest of Europe and America. To provide a sufficient supply of this article, many thousand tons of the finest mercantile navy in the world are annually employed, in trading with a people by whose government all dealings with foreigners have until recently been discouraged; and an important source of revenue, averaging from three to four millions sterling, is obtained, through a moderate duty upon its importation, by the state.

562. Although the plants of this order which are known in European gardens, are chiefly from China or North America, these form but an inconsiderable part of the whole; 7 or 8 species being all that are contained in the first of these countries, and 4 in the latter; while between 60 and 70, all beautiful trees and shrubs, are natives of the woods of South America; and about 20 more are known in the East Indies.

Order AURANTIACEÆ, *or Orange tribe.*

563. The group of plants producing Oranges, Lemons, Limes, Citrons, Shaddocks, Forbidden-fruit, and the like, is readily distinguished from the rest of the Vegetable Kingdom, by several evident characters, which give to its structure much interest; and it is also one of great value to Man, on account of the large quantity of grateful and refreshing fruit with which it supplies him, in the very climates where it is most needed. It is remarkable as being the only tropical fruit which can be introduced into this country, at a cost little exceeding that of our ordinary native fruits; and whilst it thus offers a gratification within reach of the poorer classes, it is so superior to other fruits, that it cannot be despised for its cheapness even by the richest. From the amount of duty paid upon Oranges, it has been calculated that about 272 millions are annually imported; which gives an average of nearly a dozen to each individual of the population. This abundance is due in part to the prolificness of the tree; a single individual, at St. Michael's, having been known to produce 20,000 Oranges, fit for packing, exclusive of the damaged fruit and waste, which may be calculated at a third

more. It is also due to certain qualities in the fruit itself, which allow it to be kept for a considerable time, with less alteration than fruit of any other kind. Of these qualities, one of the most remarkable consists in the thick spongy rind, which resists changes of temperature by its non-conducting power; and in the large amount of minute oil-receptacles by which the surface is occupied, the contents of which almost entirely prevent the evaporation of the watery fluid within, and, by their acridity, resist the attacks of insects, &c. from without. Hence internal decay is the only accident by which oranges are liable to be destroyed; and this does not happen for a long time, if the rind remains uninjured, so as completely to exclude the air from the interior, and if they are well ventilated, and kept free from moisture, which would cause the exterior to decompose.

564. If we examine any plant of the Orange tribe, grown in a hot-house in this country, or in the open air in its native clime, we may at once observe that it has a peculiar aspect, in consequence of the surface of its leaves being covered with minute yellowish dots. These dots are little receptacles for secretion, filled with an essential oil very fragrant to the smell, though acrid to the taste; the leaves possess some fragrance in their natural state, but, if they be crushed between the fingers, this is very much increased, part of the receptacles being then ruptured. These little cavities exist not only beneath the surfaces of the leaves and fruit, but also in the leafy parts of the flower, which owes most of its fragrance to them. On further examining the leaves, it will be observed that they are articulated or jointed at the junction of the blade with the petiole, and that the latter is expanded (more or less in the different species) into a sort of small supplementary leaf, by the development of a narrow blade from each side. In some species the leaves are pinnate; and it occasionally happens that the leaflet of one side only is developed, or that even both are absent; so that the petiole, which is then much enlarged, has to perform the functions of the true leaf, as in some other cases (§. 228). The calyx has the shape of a cup, being formed of five sepals (in some species only three) united at their lower portion, and separating above into as many

teeth; it early falls off. The petals are equal in number to the sepals; they are sometimes slightly adherent at the base; and in the Orange they are fleshy and white, with dots of green. The stamens are equal in number to the petals, or are twice, or some multiple, of their number; the filaments are rather flattened at the base, and are sometimes adherent into one bundle, sometimes into several, and are sometimes altogether free, as in the Orange itself. The pistil has a nearly globular ovarium, composed of several adherent carpels; it bears a thick tapering style, having a slightly-divided stigma at its point; and in each cell of the ovary there is a double row of ovules.

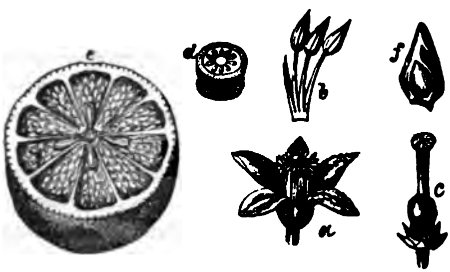

FIG. 149.—CITRUS AURANTIUM. *a*, Flower; *b*, stamens, to show the union of the base of the filaments; *c*, pistil; *d*, transverse section of the ovary; *e*, ditto of the fruit; *f*, seed.

565. During the ripening of the fruit, however, a large proportion of these ovules perish; and in the Orange and its nearest allies, the cavity of the seed-vessel becomes filled up with a pulp consisting of separate vesicles, each containing a portion of the sweet-acid fluid, which is so characteristic of the fruit of this order. The aggregation of these cannot be distinctly seen in the usual state of the common Orange, in consequence of their close adherence to one another; but in an over-ripe Orange, or in one grown in a hot-house, they are very easily separable. An important change takes place also in the structure of the carpels themselves, which will serve to illustrate the still more striking alterations that occur elsewhere. It is to be remembered that each carpel may be regarded as composed of the same elements

which form a leaf; and that in some carpels, the resemblance to a leaf is very distinct (§. 462). Supposing the two edges of the carpellary leaf to be folded together, as represented in Fig. 97, we should have the cuticle of the under surface becoming the lining of the cavity, the cuticle of the upper surface forming its external wall, and the parenchyma or fleshy tissue of the leaf intervening between them. The amount of this parenchyma is subject to much variation; and the two cuticles often undergo great changes in structure and degree of density. The ovarium of the Orange is to be regarded (as already stated) as made up of a considerable number of carpels adherent to each other; and in its early condition, the walls of these are everywhere of the same firm fleshy character. During the ripening of the fruit, however, the rind or external wall is separated from the inner wall by a quantity of spongy parenchyma, which in some species (as the Shaddock) attains a very considerable thickness; the outer walls of all the carpels unite together to form one continuous envelope; whilst the inner walls, enclosing the pulp and seeds, are easily separated from this and from each other. In the Plum, Cherry, Peach, and other stone fruits, which belong to the order Rosaceæ, the change is still more decided. In these, each fruit, which is the ripened ovary, contains but one cell; and each cell usually includes but a single ovule when mature, though at an earlier period it may have contained several. Now the lining or inner wall of the ovary here becomes greatly condensed, forming the stone; the outer membrane continues to exist as the cuticle or skin of the fruit; and it is the fleshy part of the carpellary leaf, very much increased in amount, that forms the edible portion. In such instances, the outer is called the *epicarp*, the inner wall or stone the *endocarp*, and the succulent flesh the *sarcocarp*.

566. The various species of the Orange tribe are almost all natives of the East Indies and China, whence they have been transported to other countries within or near the tropics. They nearly all contain sugar, citric acid, an aromatic essential oil, and a bitter principle having tonic properties; but these are combined in varying proportions in different fruit. Thus in the

common Orange the sugar prevails, and the acid (when the fruit is ripe) is subordinate. In the Lemon, the acid is always predominant in the pulp, and the oil is more abundant in the rind. In the Shaddock, and still more in the Seville Orange, the bitter principle manifests itself. Various species, unknown in this country, are used as articles of food by the inhabitants of the countries of which they are natives; and from some a valuable timber is derived. The Orange and its allied species require two years to mature their fruit; and, as they continue flowering all through the summer, a healthy tree exhibits, during a considerable part of each year, every stage of the production, from the flower-bud to the ripe fruit, in perfection at the same time. Most of the oranges and lemons intended for transportation to a distance, however, are gathered whilst they are still green; for if the fruit were allowed to become mature, it would spoil in the conveyance. The gathering of oranges and lemons for the British market generally occupies from the beginning of October to the end of December; and they would require to hang until the commencement of the spring, to ripen fully on the tree. It is remarkable that the Orange trees from which the fruit is gathered green, bear plentifully every year; whilst those upon which the fruit is suffered to ripen, afford abundant crops only in alternate years. The Oranges of St. Michael are the best that are known in Europe; but the tree was introduced there by the Portuguese, as it was by the Spaniards into the New World. The Orange is extensively cultivated in Spain and Portugal, where it was early introduced by the Moors; near Cordova there are trees which are considered to be 600 or 700 years old; and in Andalusia there are extensive orchards, which have formed the principal revenue of the monks for ages. In the south-east of France, also, and in the North of Italy, the orange is cultivated with great success; but it does not thrive well in the peninsular part of the latter country, except at the South. Besides the refreshment afforded to Man by the cooling fruits and delicious perfume characteristic of this order, it yields him an article of great importance in his manufactures,—lemon juice,—the chief uses of which have been formerly mentioned (§ 402).

567. The next order to be noticed is that of **Ampelideæ**, which is principally important as containing the common *Grape Vine*, which will serve as an illustration of its characteristic structure. Nearly all the plants of the group are climbers, and most of them support themselves by *tendrils*. The nature of these organs differs, in almost every tribe of plants which possesses them. If the Pea be examined, its tendrils will be seen to consist in a prolongation of the midrib or central stalk, from each side of which the leaflets arise. In some plants, this office is performed by the prolonged tips of the petals, which twine round any object in their neighbourhood that can afford them support. In the Vine, the tendrils are developed from a number of supernumerary barren flower-stalks. The flowers of the Vine grow on short stalks, which diverge from others, and these branch from the central stem; in this manner, when the fruit is ripe, a cluster is formed, differing considerably from that, in which the fruit-stalks at once proceed from the stem, as they do in the Currant. The former arrangement is called a *panicle*, the latter a *raceme*. The calyx is very small and almost undivided,

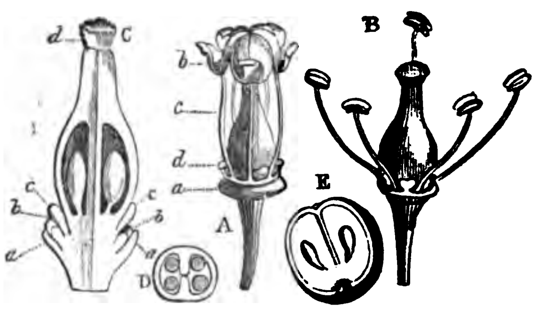

Fig. 150.—Portions of the flower of Common Vine. A, flower opening; *a*, calyx; *b*, corolla, the petals detached at the bottom but united at the top; *c*, stamens; *d*, glands. B, ovarium surrounded by the stamens. C, vertical section of ovarium, showing its two cells and ascending ovules; *a*, calyx; *b*, origin of petals; *c*, glands; *d*, stigma. D, horizontal section. E, section of ripe fruit.

looking like an expansion of the disk; within it are seen, in the bud, five petals which hold together at the point, though sepa-

rate at the base; and these are afterwards detached and carried upwards by the extension of the stamens. The stamens are five in number, opposite to the petals; there is, therefore, a whorl deficient (§. 465); and the abortive rudiments of this we find in five little glands projecting from the disk, which alternate with the fully-developed stamens. Within the circle of stamens is found a two-celled ovarium, surmounted by a single stigma, which is not supported upon a style, but seated at once upon the ovarium; hence it is said to be *sessile*. In each cell are two erect (§. 500) or ascending ovules. The fruit is, as is well known, a succulent berry, with from one to four hard seeds contained in its pulp; the original division into two cells is nearly obliterated, when the fruit is ripe. An additional character which may be remarked in the common Vine and its allies; and which is interesting as showing the affinity between this order and the succeeding one, is the tendency to a swelling or tumidity, in the branches, near the points from which the leaves proceed; and in the Vine, the young branches have the divisions into *nodes* marked nearly as strongly as they are in the Grasses (§. 148).

568. The plants of this group are naturally inhabitants of the milder and hotter parts of both hemispheres, especially of the East Indies. There is a very close resemblance in essential characters amongst them all; though in subordinate peculiarities the tendency to variation is considerable. The mode of growth, and the form of the leaves, are nearly the same throughout; and the chief obvious difference is in the size of their flowers, which are usually greenish in colour, and in the taste of their fruit. In the Fox-grape of America, for instance, the berries have a vile indescribable taste, which has been compared to the odour of the fox; in the River-grape, they are small, black, and acid, but the flowers have a delicious odour, which makes amends for their minuteness. The genera *Cissus*, and *Ampelopsis*, many species of which are well known as creepers (the most common of which is the Virginian Creeper), differ from the Vines in having the leaves divided into five distinct segments; and they are remarkable for the rich crimson hue

which these assume in autumn. Some species of these possess astringent properties, in addition to the ordinary acid of their fruit; and in the Virginian Creeper there is a considerable amount of acid in the leaves, which causes them, when bruised and applied to the skin, to raise blisters. Hence, these plants have been used medicinally in some countries; but not with any peculiar advantage.

569. Few plants have been more cherished, and more vituperated, than the Vine. It must be confessed that, if mankind could abstain from the abuse of its products, there is no tree that affords more acceptable or refreshing fruit; but the abuse has been so prevalent wherever the use has extended, and its consequences have been so pernicious, that it may be questioned whether the evil dispositions of Man have not turned that to a curse, which the Bountiful Creator certainly intended as a blessing. The cultivation of the common vine, which is not native to Europe, but which now grows wild near the coasts of the Caspian Sea, in Armenia, &c., and which probably extended, at an early period of the history of Man, over all parts of the earth then tenanted by him, may be traced to a very high antiquity. Its growth, and the preparation of wine from it, were probably branches of antediluvian history; for we read that, immediately after the Deluge, Noah planted a vineyard, and drank of the wine, even to intoxication; so that the sin of habitual drunkenness is likely to have been one of those, which led to that signal manifestation of the Divine displeasure. From Egyptian tradition, the culture of the vine appears to have been practised in that country, at the earliest period of its settlement. It was gradually spread, with the progress of civilisation and of intercourse between nations, from its native habitation in Central Asia, to Greece, Sicily, and Italy; and thence to Portugal, Spain, and France. Its introduction into Britain seems to have been due to the Romans; but the average temperature of this country is too low for its successful cultivation in the open air. With the assistance of artificial heat, however, aided by rich manure, and trained by horticultural skill, the vines grown in this country have surpassed all others in the size and luscious-

ness of their fruit. It has not been found generally worth while, however, to make wine from the juice of British grapes; since those produced in hot-houses are by far too valuable for such a purpose; and those grown without artificial heat do not contain enough sugar, to enable the fermented liquor to rival that obtained from the vineyards of warmer climates. Some centuries since, however, when foreign wines were less readily obtainable in Britain, large quantities of wine were made in the southern part of our island. Even so late as the year 1763, sixty pipes of wine resembling Burgundy were made from the produce of a vineyard belonging to the Duke of Norfolk, near Arundel Castle on the south coast of Sussex; and at the present time there are still two or three vineyards near the south coast of Devon, from which wine in small quantities is commonly made.

570. The culture of the vine as an article of husbandry extends over a zone stretching from about the 21st to the 50th degree of north latitude, and consequently about 2000 miles in breadth; and reaching in length from the western shores of Portugal to the North of India. The best wines are made about the centre of the zone; those of the north being harsh and austere; whilst the juice of the grapes of the south too soon passes into the acid fermentation, so that they are better adapted for being dried as raisins. Hence in Spain and Greece, the vineyards of the higher grounds produce the best wines; whilst the grapes produced upon the low hot shores have always to be dried. On the other hand, in Madeira and the neighbouring islands, in which the near proximity of the sea on every side tends to prevent intense heat, some of the most highly-prized wines are produced, although they are much nearer the southern border of the zone. "A vineyard, associated as it is with all our ideas of beauty and plenty, is in general a disappointing object. The hop plantations of our own country are far more picturesque. In France, the vines are trained upon poles, seldom more than three or four feet in height. In Spain, poles for supporting the vines are not used; but cuttings are planted, which are not permitted to grow very high, but gradually form thick and stout stocks.

In Switzerland, and in the German provinces, the vineyards are as formal as those of France. But in Italy is found the true vine of poetry, 'surrounding the stone cottage with its girdle, flinging its pliant and luxuriant branches over the rustic verandah, and twining its long garland from tree to tree.' It was the luxuriance and the beauty of her vines and olives, that tempted the rude people of the North to pour down upon her fertile fields. In Greece, too, as well as Italy, the shoots of the vines are either trained upon trees, or supported, so as to display all their luxuriance, upon a series of props. This was the custom of the ancient vine-growers; and their descendants have preserved it in all its picturesque originality. The vine-dressers of Persia train their vines to run up a wall, and curl over on the top. But the most luxurious cultivation of the vine in hot countries, is where it covers the trellis-work which surrounds a well, inviting the owner and his family to gather beneath its shade. 'The fruitful bough by a well' (Genesis xlix. 22) is of the highest antiquity."

571. The vine lasts to a considerable age; it spreads also to a large extent, or when supported, rises to a great height. Although it bears plentifully at three or four years, it is said that vineyards improve in quality till they are fifty years old. In France and Italy, there are entire vineyards still in existence, and in full bearing, which were in the same condition at least three centuries ago. Many vines in this country are above 100 years old. A vine existed at Northallerton, in 1785, which covered a surface of 137 square yards, and the principal stem of which was about 15 inches in diameter; it was then about 100 years old, and it increased in size afterwards, but it is now dead. There is at present a vine grown under glass at Hampton Court, which covers a surface of 22 feet by 72, or 1694 square feet; this bears seldom less than 2000 clusters every season; and in 1816 there were at least 2240, each weighing on the average a pound. Vine-growers enumerate nearly 300 different kinds of grapes, which are all,—whether black, white, blue, or varied in colour,—but varieties of the same species. The quantity of foreign wine of various descriptions imported into Great Britain

in the year 1839, was nearly *ten millions of gallons*, from which the revenue derived a duty of nearly two millions sterling. The quantity of raisins imported was about *ten thousand tons*, the duty upon which amounted to 135,000*l*. An article still more largely imported, is known under the name of "Zante currants;" of these, which are really small dried grapes grown in the Ionian Islands, the importation was in 1839 to the amount of more than ten thousand tons, the duty on which was nearly 190,000*l*. These facts will serve to show the vast extent over which the vine must be cultivated, in order to yield, to Britain alone, so large an amount of valuable products.

Order GERANIACEÆ, *or Geranium Tribe.*

572. This order is chiefly interesting on account of the large number of species which are natives of Britain, and the amount of other kinds which are now naturalized here, being cultivated for their showy and elegant blossoms. What are commonly termed *Geraniums* by the horticulturists are not really such, but belong to the allied genus *Pelargonium*. Of the real Geraniums, some species or other may be found growing wild almost everywhere, and are commonly known by the name of Cranesbill, which they have received on account of a peculiarity that will be presently noticed. If we examine almost any kind of Geranium, we shall find that, as in the last order, the stems are tumid at the points from which the leaves arise;—a character which seems of slight importance, but which often runs through a particular Natural group, and enables us to easily recognize the plants belonging to it. Several flower-stalks very commonly diverge from one centre (in the same manner as do the metal stretchers, by which the whalebones in an umbrella are spread asunder,) forming what is called an *umbel;* but in most of the British Geraniaceæ, each principal stalk bears but two flowers. The calyx consists of five ribbed sepals, which spread asunder when the flower is open; but when the petals have fallen off, they contract again around the young and tender ovaries, to which they then form an efficient protection. The petals are

also five in number, except in a few instances in which one is undeveloped; their veins are unusually prominent, and they give to the petals a streaked or pencilled appearance. These veins consist almost exclusively of air-vessels, and they serve as beautiful objects of microscopic investigation. The stamens are usually two or three times the number of the petals; in the Geraniums there are ten, and they distinctly form two rows, of which the outer one is shorter than the other; and in the Erodium or Cranesbill, also a British genus, the stamens of the outer row do not bear anthers. In the cultivated Geraniums, or *Pelargoniums*, the corolla is somewhat irregular, the two upper petals being larger than the three lower, and standing apart, so as to give the flower the appearance of having two lips. The pistil of the Geranium tribe has a singular structure. It consists of five carpels clustered together round an axis, which is the disk prolonged upwards through their centre; in each cell of the ovarium is a single seed. The styles adhere together in such a manner as to form but a single column, divided at the top into five lobes, which are the stigmas. (Fig. 151).

573. When the fruit is ripe, it resembles in a striking manner the bill of certain birds; whence the British Geraniums are known by the name of Cranesbill; and the Erodium (an allied genus) by that of Storksbill. This singular appearance is owing to a very simple circumstance. In most plants, the styles shrink up or fall off, at the same time that the flower fades; and, by the time the fruit is ripe, they have entirely disappeared. But in the Geranium the styles continue to grow and harden as fast as the fruit itself; and when the latter is ripe, the styles project from the ovaries in the form of a beak. At the time that the fruit is ripe, the seeds are sown in a very curious manner. The carpels and styles are still clustered together round the central axis; but the latter shorten in drying; and as they adhere so closely at their points that they cannot separate there, they actually cause the separation of the carpels at their base; and these, when torn up as it were by the roots, curve towards the top of the style, and at the same time open by the face which was previously adherent, so as to let the seed drop out. This

action takes place suddenly: and it may be noticed in any common Geranium whose fruit is mature, if gathered before the dew is off and then put in the sun; the effect of its heat will be to detach first one and then another carpel with a snapping sound, — the jerk serving to scatter the seeds. This peculiar mode of separation is common to the whole order, and is very characteristic of the plants included in it.

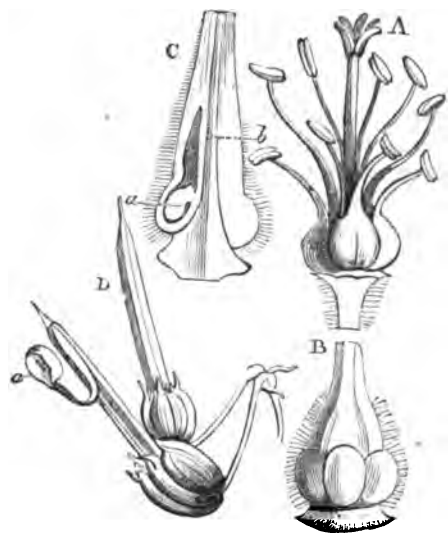

FIG. 151.—STRUCTURE OF FLOWER OF MEADOW GERANIUM. A, stamens and pistil; B, the lower part of the pistil, showing the clustered carpels; C, section of the pistil, showing a, the ovule, and b, the prolonged axis, round which the carpels are clustered, and which forms the hard beak in the ripe fruit. D, a couple of ripe fruit, enveloped in the calyx below, the styles projecting above; a, is a carpel which has been detached by the hardening and contraction of its style.

574. The Geraniaceæ are extensively diffused over the globe, some genera being restricted to one quarter, and others to a different part. The chief residence of the Pelargoniums is at the Cape of Good Hope, from which all the showy Geraniums (so called) which ornament our windows and gardens, have been derived. These have been greatly improved by cultivation, and many new varieties have sprung up; and their number has been still further extended by hybridism, which can be very effectually performed in this group, the offspring almost always presenting a complete intermixture of the characters of its parents. Thus, if we take the pollen of a plant with red flowers, and place it upon the stigma of one which has white flowers, the

seed will produce a plant having light-red flowers; or if we cause a sort with large unsightly flowers to intermix with one having small neat flowers, we shall probably obtain a variety having large flowers that are as neat in appearance as those of the small flowered kind. This intermixture will only take place, however, among varieties of the same species, or among species nearly related to each other; there are some Pelargoniums which will not hybridize together; and the Pelargonium is not fertile with the Geranium. The Geraniaceæ are not marked by any very active properties; they possess, however, some astringency, and also an aromatic resinous principle. The stem of a foreign species of Geranium burns like a torch, and gives out an agreeable odour. The root of an American species is considered a valuable astringent, and is known by the name of Alum root. The British species commonly termed Herb-Robert, is held in repute for its medicinal virtues in some parts of the country.

575. Very nearly allied to the Geraniaceæ is the small order Tropæoleæ, of which the members are all natives of tropical America, but of which one species is now commonly naturalised in our gardens under the name of *Nasturtium* (which is, however, an incorrect one), sometimes abbreviated into Sturtion, or occasionally Trophy-cress. The common name refers to the similitude it bears in taste, smell, and general properties, to the true Nasturtia or Cresses;—a similitude so great, that the same insects resort to and feed on both. The plant is cultivated in Britain for the sake of its unripe ovaria, which possess an agreeable pungency of flavour, and are pickled to be used like Capers as a sauce to boiled mutton. This order differs from the last, chiefly in the following particulars. The sepals of the calyx are unequal in size, and one of them is provided with a long distinct spur (of which a rudiment, however, may be traced in Pelargonium); this is subject to great varieties of form; indeed a series of monstrosities, such as may often be easily collected from a single bed of these plants, presents many curious phenomena. There seems a great tendency towards the return to a regular form, by the equalisation of the sepals; in some instances the

spur will be found nearly or altogether deficient; whilst in others it would be double or triple, the three being sometimes united, sometimes divergent from each other. In one curious specimen which came under the Author's notice, a second spur grew from the first,—not downwards, however, but upwards into the flower, just as if we push back the finger of a glove, so as to project into the part that receives the hand. The petals are also more or less irregular, three being smaller than the rest, and these being occasionally undeveloped. The stamens are eight in number, and are perigynous or adherent to the calyx (§. 498). This, then, is an instance in which an exception occurs to the character that has been taken as the chief guide in classification; for although the perigynous stamens, considered in themselves, would cause the order to be removed into the next class, yet its affinity with other Thalamifloræ, and especially with Geraniaceæ, is so manifest, that it cannot be properly removed from that group. The ovary is made up of three carpels, adherent as in the last order, around a central elongated axis; these each contain a single seed.

576. Another allied order is that of BALSAMINEÆ, the *Balsam* tribe; this has not, however, any of those medicinal virtues which might be inferred from its name, but consists only of a small number of plants, which are esteemed for the beauty of their flowers and their elegance of aspect. Of these, one species is a native of Britain, though it is rarely found wild; and this is remarkable for the curious manner in which its seed-vessel opens (§. 419). There is greater irregularity in the flower than in either of the last two orders; so that the nature of its parts might not be understood at first sight. The sepals are five in number, but unequal and irregular in form; the two upper and inner ones are adherent, while the lower one is spurred. There are only four petals; and these are adherent in pairs; so that the corolla appears as if it consisted of two only. The stamens are five in number, and their position is regular; so that, by comparing their places with that of the petals, it becomes evident that each of the apparently-single petals consists of two, and that a fifth petal, which should occupy the space between them,

is undeveloped. The ovarium is made of five carpels clustered together, their cavities remaining separate; the stigma is *sessile* on its top, as in the Poppy (§. 523), and exhibits a greater or less division into five parts. The Balsams usually grow in damp places among bushes; and one or two species are found in nearly every quarter of the globe.

577. Another small order, allied to the Geranium tribe, is that of Oxalideæ, or *Wood Sorrel* tribe; which is chiefly deserving of notice, on account of an important product yielded by some of its species. The Wood Sorrel (*Oxalis*) and its allies are herbaceous plants, which abound most in the warmer temperate regions, especially in America and at the Cape of Good Hope; but two species are found in the woods and shady places of this country. In the structure of their flowers, they differ but little from Geraniaceæ; their calyx and corolla each consisting of five equal leaflets; their stamens being ten in number, arranged in two rows, of which the outer one is the longest; and their ovaria consisting of five adherent carpels. The stamens are generally united at the base, however, into a single bundle; there is no central axis in the midst of the carpels; the styles are distinct; and there is a minute but important difference in the structure of the seed. They are further distinguished by the division of their leaves, which are generally compound; and, if simple, become so merely through the want of development of some of the segments. In this group, as in the Balsamineæ and Geraniaceæ, there is a provision for the scattering of the seeds by the sudden rupture of their integument, which possesses elasticity enough to expel them with some force. The Wood-Sorrel is one of the plants whose leaves droop very evidently at night. The property which is most characteristic of the Oxalideæ is the acid nature of their juices, which is chiefly to be noticed in the common Wood Sorrel of this country. The

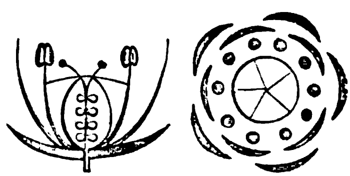

Fig. 152.—Diagram of the flower of Oxalideæ.

acid is peculiar in its properties, and is named *oxalic* from its existing in this plant, from which, indeed, it was at first obtained. Its uses in the arts have already been noticed (§. 401). The quantity obtainable from this and other plants which furnish it, is too small for the supply of these; since, from twenty pounds of the leaves of the Wood Sorrel, which yield about six pounds of juice, not quite three ounces of oxalate of potash can be obtained. Since, therefore, it has been ascertained that the acid might be obtained pure by the action of nitric acid upon sugar, this mode of producing it has been generally adopted, except in places where the plant is very abundant. One Indian subdivision of this tribe differs from the rest, in the larger size of the species belonging to it, which grow into bushes or even trees; and some of these are cultivated for the sake of the juices afforded by the leaves, flowers, and fruit, which are of a pleasant acid character, and are esteemed as cooling remedies in fevers. One species, moreover, is remarkable for the great irritability of its leaves, which perform movements resembling those of the Sensitive Plant; and there is a foreign species of Oxalis, that has in some degree the same property.

578. The last order of Thalamifloral Exogens to be here noticed is that of RUTACEÆ, the *Rue* tribe, of which several species are cultivated in our gardens, though none are originally natives of this country. All the plants of the order are remarkable for their powerful odour, which is usually of a nauseous character; and this is due to the quantity of essential oil, secreted in little cavities beneath the cuticle of the leaves, the place of which, as in the Orange tribe, is marked by half-transparent dots. To this group belongs the Fraxinella, formerly mentioned (§. 374) as rendering the surrounding air inflammable in warm weather, by the quantity of this oil which it diffuses through it. The common Garden Rue will give a very good idea of the structure characteristic of the order. The parts of its flower, however, are arranged in fours; whilst those of other species are disposed in fives. The calyx consists of four sepals diverging widely from each other; and within these, alternating with them, are four petals. The stamens are eight in number; and they arise from a

fleshy ring surrounding the ovary. Upon this ring is seated the ovary, which consists of four carpels united into one mass. These do not stand upright, however, as they usually do; but spread

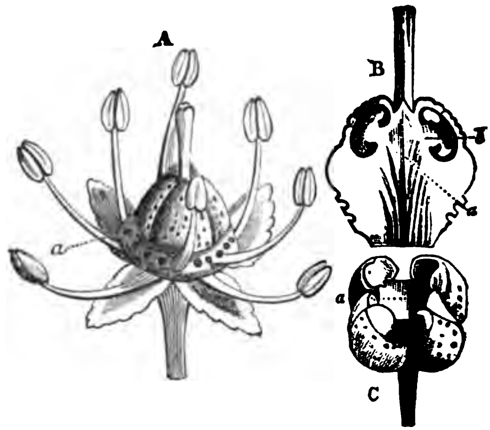

FIG. 153.—GARDEN RUE. A, magnified flower deprived of petals; *a*, fleshy ring from which the stamens arise; B, section of ovarium; *a*, the gynobase; *b*, the placentæ. C, a seed-vessel after bursting; *a*, the gynobase.

away from each other at the base, being arranged on the sides of a conical disk, which rises up between them, but is not continued into the style. This disk is termed the *gynobase*, or base of the female organs (§.484.) The style is single, being formed by the adhesion of those of the several carpels; but it separates at the top into four stigmas. The seed-vessel, when ripe, splits into four valves, leaving the thick hard gynobase in the centre. The number of seeds contained in each varies considerably, but is almost always less than that of the ovules. In the common Rue, there are about four ovules in each cell; but only one of these is developed into seed. In others the ovules and seeds are more numerous. One genus (Correa) of this order presents an interesting anomaly, of a similar character to that which has been mentioned as occurring in the order *Tropæoleæ;* the petals cohere together into a tube, so that the plant is really Monopetalous;

but it is not placed in that division of the group, since in its general structure it is so closely allied to the Rutaceæ, that it cannot be separated from them.

579. The principal habitation of the Rue tribe is the South of Europe, whence it extends through the temperate portion of the Old World, rarely advancing within the tropics. The common Rue was formerly much esteemed in medicine; it was mentioned with approbation even by Hippocrates, and for many centuries it was considered a preventive of contagion, and was known under the name of "herb of grace." It is now, however, seldom employed, except by village doctresses.

580. The following table* will be found to express, in a concise form, the most evident points of difference among such of the foregoing orders as contain Plants found in Britain; so that the Student will have little difficulty in assigning to its correct place a specimen of any one of them, which he may meet with. It is to be remembered, however, that there are orders of minor importance, which are not altogether excluded by these characters, and that the specimen *may* belong to some of them. But as all those which include the commonest wild and garden flowers have been adverted to, this is not likely to happen.

CLASS EXOGENS.—SUB-CLASS THALAMIFLORÆ.

Flowers possessing calyx and corolla, the latter composed of distinct petals. Stamens, as well as petals and carpels, arise at once from the disk; except when sometimes slightly adherent to the sides of the ovary.

A. *Stamens more than* 20.

a, Ovary superior.

α, Leaves without stipules.

Carpels distinct	*Ranunculaceæ*,	504.
Carpels united	*Papaveraceæ*,	523.

* By the use of such a table as this, almost any British plant may be referred, with great facility, to its proper Order in the Natural System. For example, we

β, Leaves with stipules.		
Calyx imbricated	*Cistaceæ*,	536.
Calyx valvate.		
Stamens monadelphous . . .	*Malvaceæ*,	546.
Stamens distinct	*Tiliaceæ*,	557.
b, Ovary partly inferior	*Nymphaceæ*,	520.
B. ***Stamens less than*** **20.**		
a, Leaves with stipules; carpels consolidated.		
α, Placentæ parietal.		
Leaves unfolded from spiral coil . .	*Droseraceæ*,	540.
Leaves unfolded straight	*Violaceæ*,	538.
β, Placentæ in axis.		
Fruit with beak	*Geraniaceæ*,	572.
Fruit without beak.		
Stamens monadelphous . . .	*Oxalideæ*,	577.
Stamens opposite petals	*Ampelideæ*,	566.
b, Leaves without stipules.		
α, Carpels distinct, anthers with valves . .	*Berberideæ*,	519.
β, Carpels consolidated.		
Placentæ parietal, stamens tetradynamous .	*Cruciferæ*,	529.
Placentæ in axis, stamens not tetradynamous.		
Styles distinct.		
Capsule one-celled, with free central placenta	*Caryophylleæ*,	541.
Capsule many-celled	*Linaceæ*,	543.
Styles united, leaves dotted	*Rutaceæ*,	578.

pick in our walk through a lane a specimen of the common Chickweed, or Stitchwort. The veined structure of its leaves, the prevalence of the number five in its flowers, and its general aspect, prevent any doubt that it is an Exogen. On examining the structure of the flowers, we at once perceive that the stamens are hypogynous; for we may pull off both calyx and corolla, without detaching them from the disk, on which they are separately inserted. The plant belongs, therefore, to the sub-class Thalamifloræ. The stamens may be from five to ten in number; it is comprehended, therefore, in the second division (B) of the table. Its leaves are readily seen to be without stipules, and we consequently look for it in the group of orders below *b*. On examining the carpels, they are seen to be consolidated; and, on cutting across the ovarium, the placentæ are found to be central; it must, therefore, belong to one of the three lowest orders in the table. It cannot be a Rue, since its leaves are destitute of glandular dots; it must, therefore, be either one of the Linaceæ or of the Caryophylleæ; the most *obvious* difference between which is usually in the structure of their calyx, as formerly explained (§. 543); but the most *constant* difference is that which is specified in the table as existing between their fruit. When the plant has thus been referred to its proper order, the whole of the general account given of that order will be found applicable to it, and to other species closely allied to it.

Sub-class II.—CALICIFLORÆ.

581. It will be remembered that, in this division of the Exogenous Phanerogamia, the sepals of the calyx are always adherent to each other, and that the petals and stamens appear to arise from them, rather than from the disk or receptacle, to which they may really be traced. Taken as a whole, this division cannot be regarded as containing a number of species, of essential service to Man, equal to that which has been shown to be comprehended within the former one; yet several orders of very great interest and importance are comprehended in it. To these it will be desirable to give our principal attention, passing over a large number of other groups with little or no notice.

582. The first order which presents itself is that of Celastrineæ, in which the common *Holly* is placed by many Botanists. This order is characterised by the possession of four or five sepals, united at the base, and of an equal number of petals alternating with them. The stamens, again, are the same in number, and alternate with the petals; and they are perigynous (§. 498) in their insertion. The ovarium is superior, and is composed of several adherent carpels; it is partly enveloped in a large fleshy disk, and usually contains from two to four cells, each of which may include one or several ovules. The style is single, but separates at the top into two or four stigmata. The species of this order are mostly trees or shrubs, the flowers of which are not conspicuous. The section to which the Holly belongs is distinguished by having the petals in some degree adherent to each other; and hence it has been placed by some Botanists, as a separate order, among the Monopetalæ. The common *Holly* is one of the few British species of this order, which is pretty generally distributed over the surface of the globe. It is a very slow-growing tree, rarely attaining any great size; its wood is much used by turners (being one of the hardest of the white woods), especially for the manufacture of the toys known as Tunbridge ware. The inner bark abounds in a tenacious substance, which, when separated, is known as bird-lime, from the

use to which it is put in entrapping birds. The bark and leaves are bitter, and have been used as a substitute for other analogous substances, in the cure of intermittent fevers. From the leaves of a species of Holly which is a native of South America, the inhabitants of that country make an infusion, which is employed as *tea* is among us; this is known as *Maté* or Jesuits' Tea, and is very extensively consumed in Brazil, Paraguay, Chili, and Peru. Another species which inhabits the Southern part of North America, furnishes the Indians with a similar article, which is used by them as a medicine, and also as a draught of etiquette at their solemn councils. Another British species is the *Euonymus*, known under the name of *spindle-tree*, or *prick-wood*, from the uses to which it is applied. It has a wood which, without being hard, is very tough; and this was formerly much employed in making spindles for the spinning-wheel. Now that the *jenny* has superseded the distaff, however, this is little used except for making toothpicks and skewers; and also by watch-makers, for cleaning delicate machinery, for which it is very well adapted on account of the fine point with which it may be worked without breaking. The second of its common names seems to render it not improbable, that it was formerly used in the manufacture of those skewer-like pins, which were employed to hold dress together as late as the reign of Henry VIII., when the manufacture of metal pins became more general. The fruit and the bark of this tree have properties, which render them poisonous to most animals, and which give them purgative and emetic effects if taken by man.

583. Nearly allied to the last order is that of RHAMNEÆ, or the *Buckthorn* tribe; which may, however, be readily distinguished from it by the position of the stamens, these being here found opposite to the petals, or alternating with the sepals. The structure of the calyx is also different,—that of the Rhamneæ being *valvate* (*i. e.*, the sepals, before expanding, having their edges in proximity with each other), whilst that of Celastrineæ is somewhat imbricated (the sepals overlying one another). The ovarium is partly enveloped, as in the last order, by the fleshy disk; and this, as the fruit ripens, grows over the ovary, and

completely encloses it. The species of this order are distributed over nearly the whole world, with the exception of the arctic regions. They are mostly shrubs or low trees which are generally remarkable for their spiny character; this manifests itself strongly in the common Buckthorn of this country, and in the Christ's Thorn, which abounds in Greece and Palestine, and which has been naturalised in our gardens. The latter derives its name from the tradition that our Saviour's crown of thorns was made from it. The spines are, as formerly explained (§. 307), undeveloped branches; and a little examination of any spiny bush will make this evident, since all stages of development may be found, between the simple thorn and the complete branch. As already stated, cultivation has a tendency to do away with this character, by supplying the plant with nutriment sufficient to develop the buds that would otherwise be abortive. Upon the final cause, or object, of this curious provision, the following excellent remarks, by an eminent Botanist, may be quoted: "In open barren tracts of country, the very circumstance of the sterility of the soil must prevent the production of many plants; and of those which grow, few will be enabled to perfect many seeds. It is necessary, therefore, to protect such as are produced from extermination by the browsing of cattle; otherwise not only would the progeny be cancelled, but also the present generation would be cut off. And what more beautiful and simple expedient could have been devised, than ordaining that the very barrenness of the soil, which precludes the abundant generation by seed, should at the very same time, and by the very same means, render the abortive buds a defensive armour to protect the individual plant, and to guard the scantier crop, which the half-starved stem can bear?"

584. The inner bark and fruit of most species of this order are possessed of active purgative powers; and some of them are also emetic and astringent. The syrup made from the juice of the berries of the common Buckthorn, was formerly much used in medicine; but, as its operation is attended with much discomfort, it is now seldom employed except for administration to dogs. The berries afford, however, a valuable colouring matter,

which is used in dyeing. The "French berries" of the shops, from which a beautiful yellow is obtained, are the unripe fruit of this plant; and from their juice, when they are ripe, the colour termed sap-green is prepared. Another species affords the colour with which yellow morocco leather is tinged. The fruit of a species allied to the Christ's Thorn, however, contains a large quantity of gummy matter, without any substance possessing active properties; this, which is known under the name of the *jujube*, is a favourite dessert in Italy and Spain, either when fresh, or when dried as a sweetmeat; and losenges made from it are much employed in this country as a remedy for coughs. The *Lotus*, the fruit of which has been celebrated from the time of Homer, also belongs to this order. It is a native of Persia, and grows wild on the north coast of Africa as well as in its interior; and its fruit is eaten by the inhabitants, wherever it grows. It is converted into a sort of bread, by drying and pounding; and from its juice, when pressed out and mixed with water, and afterwards fermented, a sort of wine is commonly made. The leaves of one Chinese species are used for tea by the poorer classes in that country; and another produces a sort of fruit, which is said to resemble a pear in flavour, but which is nothing else than the flower-stalk become fleshy.

585. Passing over several small orders of little importance, we come to that of TEREBINTACEÆ, which contains a large number of species inhabiting tropical countries, distinguished by their resinous secretions, and, at the same time, by their poisonous properties. The number and arrangement of the parts of the flower differ considerably in the different sections of the order; so that many Botanists subdivide it into three or more. The flowers are sometimes complete, but not unfrequently one or other set of organs is suppressed in some of them, so as to render the plant *polygamous* (§ 483); and some species are diœcious. The sepals are from 3 to 5 in number, more or less united together, and imbricated. The petals, when present, are equal in number to the sepals; but they are occasionally absent; they alternate with the sepals, and are sometimes adherent to each other. The stamens are either equal in number to the

petals, or are twice as numerous, and are inserted at the bottom of the calyx, or around the ovary. The carpels are sometimes distinct, and sometimes adherent; but the styles are always distinct. The ovules are few in number in each carpel, and are usually solitary. Most of the species are trees or shrubs, having alternate leaves, which are usually compound. The resinous matter is chiefly contained in the bark, whence it frequently exudes naturally, or may be drawn by incisions. Gum mastic (§. 377) and Chian Turpentine (§. 375) are obtained from species of this order; as are also Sumach and the Japan and Chinese

FIG. 154.—ANACARDIUM OCCIDENTALE, OR CASHEW-TREE.

black varnish, and probably Olibanum. The fruit is very commonly acrid and astringent, and these qualities usually exist in some degree in the bark also. The well-known Cashew-nut of the East and West Indies is produced by a plant of this order.

Its appearance, whilst still connected with the plant, is very curious. The nut is borne at the extremity of a fleshy fruit considerably larger than itself; which is nothing else than the peduncle or flower-stalk enlarged and become succulent. This fruit, which is termed the apple, has an agreeable acid flavour, slightly astringent, and is much esteemed in the West Indies, where the juice expressed from it is fermented and made into a kind of spirit. Between the two layers of the pericarp or ripened carpel, there is found a considerable quantity of inflammable oil, which is so acrid as to blister the skin if the fingers or teeth be used in removing the shell. The kernel abounds with a milky juice, and is much esteemed for its flavour. The juice of the nut of an allied species is of a deep black when ripe, and leaves an indelible stain if applied to linen, &c.; so that it makes an admirable natural marking-ink. The Mango, a fruit highly prized in India, which has been naturalised in the West Indies also, is produced by another species of this order; several varieties of the fruit are cultivated, differing much in size and flavour. They vary in weight from a few ounces to several pounds; some have a most delicious, aromatic, sweet, and slightly acid taste; whilst in others, the resins so much abound that the flesh is ill-flavoured, and, being at the same time fibrous, has been not unaptly compared to a mixture of "tow and turpentine." The tree is a very handsome one; as is also that from which the black varnish of India is obtained. This varnish, whilst still liquid, is so acrid in its properties as to blister the skin, if allowed to touch it. A fruit much esteemed in the south of Europe, as well as among Eastern nations, is the Pistachio nut, which is the produce of one of the diœcious species; and in Sicily, a ceremony similar to the marriage of the Palms (hereafter to be described) is performed, in order to ensure the fertilisation of the seeds.

Order Leguminosæ, *or Pea Tribe.*

586. This is one of the largest and most important orders of the whole group. There are few which are more easily recognised, or in which greater interest is usually taken. It is ex-

tremely rich in plants useful in various ways to Man. Some furnish him with a large quantity of wholesome and palatable food for himself, such as the Pea, Bean, Lentil, &c.; whilst others afford equally nutritious food for cattle, such as Clover and Lucerne. Others yield valuable dyes, such as Indigo and Logwood; and others again have stems which serve as excellent timber, such as Brazil-wood, Rosewood, and the American Locust-trees. From others are derived valuable medicinal products, such as Senna and Cassia, or Gums, as that of the Acacia. Others, again, are attractive on account of their beauty, such as the Laburnums, Robinias, &c.; and others are interesting on account of physiological peculiarities, such as the Sensitive-Plant (§. 421), the Gleditsias (§. 238), and the New Holland Acacias (§. 228). Between all these there is a strong *family likeness;* but there is every variety of *size* among the very numerous species which this order contains; some being humble plants, whilst others are lofty trees. The most important point in which they all agree, is in the structure of their fruit, which is a *pod* or *Legume;* whence the name of the order is derived. A legume may be thus distinguished from all other kinds of fruit. It is a carpel which grows long and flat, and separates when ripe into two valves or halves; it usually contains several seeds, which are attached to one angle only of the inside of the carpel. A Pea-pod is as apt an illustration as any that can be furnished; and, by referring to Fig. 96, the mode in which the pod is formed from the carpellary leaf will be at once evident. The ovules proceeding from the thickened edges of this leaf, which are folded together, are attached alternately to the one valve and the other; so that, when the pod is opened along the *suture*, or line of adhesion, (as is commonly done in shelling peas) half the seeds remain attached to each valve and lie in its hollow. The seed-vessels of all the plants of this order, however, must not be supposed exactly to resemble the Pea-pod; they may be longer or shorter, larger or smaller, harder, thinner, or differently coloured, or may contain more or fewer seeds; but they are always formed essentially upon the same plan.

587. A very large number of the order are further dis-

tinguished by a singular arrangement of the petals, from which they have been termed *Papilionaceous* plants, owing to the resemblance which their flowers bear to a Butterfly at rest. Of this structure, the common Pea is an excellent illustration. If we examine its flower, we shall find a calyx composed of five small nearly equal sepals united into a short tube. The corolla is much larger, and consists of five petals, one of which greatly surpasses the rest in size, standing at the back of them, and over-wrapping them before the flower expands; this is called the standard or *vexillum*. In front of this are two small petals, which stand nearly parallel with each other, converging a little at the point; these are the wings, or *alæ*. They are carefully folded over a boat-shaped curved part of the corolla, which is placed in front of all the rest; this part, termed the keel, or carina, is formed of two petals, which are slightly adherent at their lower edge, but which are separately inserted at their base.

588. There is considerable variety, in this order, as to the number and degree of adhesion of the stamens. The *Papilionaceous* division of it may be separated into those which have their stamens united, and those in which they are distinct. The former group contains all the European species, such as Peas, Beans, Vetches, Clover, Trefoil, &c. The stamens are usually double the number of the sepals (of which there are occasionally only four); and very commonly one of them is distinct, whilst the rest are united at their edges, as is the case in the common Pea, Vetch, &c. The division of the Papilionaceous Leguminosæ having the stamens separate, contains few but New Holland species. The ovary is a tapering green hairy body, gradually narrowing into a style, which ends in a minute stigma. It is one-celled, and is to be regarded as consisting of but a single carpel; sometimes, however, two or even five carpels are to be found in the centre of the flower.

589. In another division of the Leguminosæ, containing the Senna, Logwood, Tamarind, and many other interesting species, the flowers present a much nearer approach to regularity. Their petals spread equally round the pistil, as in other plants; and

their stamens also are spreading and separate. A degree of that irregularity in size, however, which is so striking among the *Papilionaceæ*, is here still evident; some of the petals or stamens being larger than the remainder. Few of this group are ever seen in this country; but in foreign climes they are very abundant.

590. The third division of this order comprehends those which have flowers formed upon the plan of the last,—that is, not being papilionaceous,—whilst the number of stamens is much greater, being triple or quadruple that of the sepals. The flowers are extremely minute, and grow in compact clusters; the stamens have very long, slender, and separate filaments. This is the structure of the division which includes the *Mimosas*, amongst which is the Sensitive Plant. Many of these have a very elegant appearance, the clusters of flowers which they bear being numerous, and often presenting gay colours.

591. Besides the peculiar structure of the fruit, in which these subdivisions all agree, the entire absence of a separate albumen,—so that the cotyledons are fleshy, and occupy with the embryo the whole interior of the seed,—is a character of great importance, which prevails through the whole group, and shows it to be a natural one. The number of species already known is very considerable, certainly not less than 4000; and many more must remain to be discovered. The order is diffused over the whole habitable globe. Some species of it have a very extensive range; whilst others are restricted to particular countries. The Papilionaceous division with united stamens contains most of the former; but these appear to flourish best in temperate and moderately warm latitudes, diminishing in number towards the poles, and giving place to the Mimosa and Cassia tribes nearer the equator.

592. The properties of the different species of this order are so various, that it is difficult to enumerate them all. Their difference may also appear to invalidate the principles formerly laid down, respecting the correspondence between structure and properties (§. 479); for, whilst some of them seem to be remarkable for nothing but the large quantity of tasteless gum which

they contain, others are violently irritant, and others strongly astringent. The seeds of the common Laburnum, for example, of which the flower and the pod very much resemble those o the Pea, are violently emetic and purgative, and have proved absolutely poisonous to children. The seeds of other species are very bitter, and are valued in India for their tonic virtues. The character of the juices which may be extracted from the wood, is equally various. This apparent exception, however, does not really weaken the principle; since the number of points of difference among the several tribes is so great, that there can be little doubt that they might be subdivided into several orders, each of which might be characterised by properties peculiar, or nearly so, to itself. Having already adverted to some of the best known among the useful products of this order, we may here mention a few others. The pulp of the Tamarind, which is so grateful in thirst on account of the large quantity of acid it contains, lies between the seeds and the valves of a legume; as does also that of the Cassia, which has a sweetish taste, and which is useful as a mild aperient for children. Licorice is derived from the juice of the roots of the plant which yields it. The juices of other species are powerfully astringent, and are used both in medicine and in arts; of this kind are Catechu, (§. 365), Kino, and other substances. The bark of the New Holland Acacias has been introduced into this country as a material for tanning. The fragrant resins, called Balsams of Tolu and Peru, which are in much use for burning as perfumes, and for medicinal purposes, are the produce of a South American species. Full details regarding Indigo, one of the most valuable products of this order, have been given on a former occasion (§. 388). Some species, which are found in the West Indies and in South America, contain juices which have a remarkable power of intoxicating fish, rendering them easy of capture, without injuring their wholesomeness as food.

593. The next order is one of nearly equal extent and importance; and contains, like the Leguminosæ, a large number of species having the same general resemblance, yet differing in the structure of many important parts. This is the order

ROSACEÆ, or *Rose* tribe, to which belong not only Roses and their immediate allies, but a large part of our most valued fruits, which seem very unlike each other, such as the Strawberry and Apple, the Raspberry and Pear, the Medlar and the Almond, &c. They all agree, however, in the general plan of the structure of the flower, which may be studied in almost any of the ordinary wild species. The Strawberry flower will, perhaps, at first serve the purpose better than the Dog Rose, or any of the true Roses; on account of a peculiarity in the latter presently to be mentioned. On looking at the outside of the Strawberry flower, we observe what is apparently a calyx consisting of ten sepals; this would be an exception to the general rule of the group, which is to have only four or five parts in the calyx; and, on looking further, it is seen that these leafy parts are arranged in two rows, of which the lower or outer one may be considered as formed by bracts. The corolla consists of five (rarely four) equal petals; and within these is a large number of stamens. Up to this point, then, we find nothing to distinguish Rosaceæ from Ranunculaceæ; but, upon looking at the position of the stamens, we observe that, instead of rising directly from the receptacle beneath the carpels, they seem to grow out of the side of the calyx. Hence, whilst the Ranunculaceæ mostly belong to the Linnæan class POLYANDRIA, the order Rosaceæ nearly corresponds

FIG 155.—AGRIMONIA EUPATORIA. *a*, flower, showing the twelve stamens; *b*, the five pistils.

with the Linnæan class ICOSANDRIA; some, however, belong to the class DODECANDRIA, as the *Agrimony* (Fig. 155.) The pistil of the Strawberry is very much like that of a Crowfoot; for it consists of a large cluster of non-adherent carpels, each having its own style and stigma, and containing a single seed. The transformation of such a flower to the fruit of the Strawberry seems very strange, until the process is understood. When the corolla has fallen off, and the calyx has closed on the tender fruit, the receptacle on which the carpels are set, gradually swells, and separates them from each other, bearing them on its outside. It becomes, at last, the soft juicy fruit; and what appear to be the seeds on its outside, are in reality the carpels, which were originally in proximity with each other, and are now dry and in close contact with the real seed-coats. The calyx remains at the base of the swollen receptacle.

594. It is principally in the number of carpels which undergo development, and in the degree in which these are united together, that we meet with variety in the structure of the flowers and fruit of this order. In the Raspberry, we find the structure of the Strawberry but slightly modified. The calyx has evidently here but five parts; the petals are five in number; the stamens are indefinite in number and adherent to the calyx; and the carpels are numerous and distinct, and are supported upon a fleshy receptacle. In the ripening of the fruit, however, this receptacle does not enlarge, as in the Strawberry, but remains as the white hard *core* of the fruit; and the fruit itself consists of the carpels, which, instead of becoming dry, acquire an increase of juice; and it is the soft fleshy walls of these carpels, that form the succulent part in which the seeds are imbedded, and from which the core may be withdrawn.

595. If we now turn our attention to the Rose tribe, we shall find that the flower is constructed upon a plan which appears similar, until we examine the centre of it, and there we find a tuft of stigmas without any visible carpels. On looking further, however, and pressing the flower forcibly, we find that the styles rise up from the neck, as it were, of an oblong green body which, being below the calyx, looks like an inferior ovarium.

On splitting this body perpendicularly it will be perceived that it is in reality the tube of the calyx, formed by the adhesion of the sepals, which closely envelops the seed-vessels, and is contracted into a narrow orifice at the point whence the styles arise. The ripe fruit of the Rose, known by the names of Hip, Hep, or Haw, is nothing else than this tube of the calyx,—which may be regarded, perhaps, as a hollow prolongation of the receptacle, —turned red and fleshy; and in its interior will be found the carpels, changed to bony grains. The Apple and Quince, and their allies, are constructed very nearly upon the same plan. The principal difference consists in this, that the ovaries and the tube of the calyx completely coalesce, and form one body, which becomes the fruit. The eye at its end marks the point from which the calyx spreads out; this is better seen in the Medlar. The principal part of the flesh of the Apple consists of the tube of the calyx or the prolonged receptacle; but in its interior are found the five carpels, whose thin walls are somewhat horny. In the Medlar, these are thick and have a bony firmness.

596. In the *Almond* tribe, which includes the Plum, Apricot, Peach, Nectarine, Cherry, and all similar fruits, there is only one carpel developed; and this in time changes to the fruit, which is termed a *drupe*, consisting of a hard shell enveloping the kernel, and itself inclosed in a soft flesh. These all agree in the peculiar properties which they derive, from the presence of a certain quantity of Prussic Acid (which, when of full strength, is one of the most violent poisons known) in some part of them,—usually either the seeds, or leaves, or both. The quantity is so small as to cause no danger in making use of such parts, unless this ingredient be concentrated in any artificial mode, as it is in what is called Laurel Water, which is distilled from the leaves of the *Prunus Laurocerasus*, or Cherry Laurel, and is used for giving a flavour to various sweet dishes and liquors.

597. This order principally abounds in the cold and temperate regions of the northern hemisphere. In fact, scarcely any species of the Rose, Apple, and Almond tribes are found elsewhere. There is a small group, however, distinguished from the rest of the order by the constant absence of petals, which abounds at the Cape of Good Hope, where it represents the Rosaceæ of

Europe. Of this group (which is ranked by some as a distinct order) the British genus *Sanguisorba*, or Burnet, is an example; the Latin name of which is derived from its supposed power of stanching the flow of blood. Another British genus belonging to it is the *Alchemilla*, or Lady's Mantle, one species of which is common in fields and gravelly soils. This group is characterised by a greater degree of astringency, than that which usually exists in the true Rosaceæ; although many of the latter also possess this character. The roots of the *Potentilla*, or Cinquefoil, and of the Tormentil, have been used in tanning; and the roots of a kind of Bramble afford a popular astringent medicine in North America. The leaves of the Sloe and other species have been used as substitutes for tea; and the fruit of the common Dog-rose and other allied species has a degree of astringency, which renders it useful in medicine.

598. The next order which will be here noticed is that of RHIZOPHOREÆ, the *Mangrove* tribe, which is chiefly remarkable on account of the singular mode of growth observed in the trees belonging to it. The Mangroves are tropical trees, growing on the banks of large rivers, or on the sea-coast, and even within the bounds of the ocean as far as low-water mark. Their mode of rooting consists, not like that of ordinary trees, of divisions of the stem beneath the ground, but (as it were) of arches of roots above it, so that a more extended base is formed, and a firmer hold established, in the loose and swampy soil. From the summit of these overbending roots, the trunk of the Mangrove springs, as shown in the ad-

FIG. 156.—MANGROVE TREE.

joining figure. The calyx in this order is formed of from 4 to 13 adherent sepals; and the petals are equal in number to the sepals, and are inserted upon them. The number of the stamens is double or triple that of the petals. The ovarium is two-celled, being formed by the union of two carpels, which have separate cells; and each cell contains several ovules. But in the ripe fruit, we find but one cell and one seed, this having been developed at the expense of the others. These seeds are peculiar on account of their power of germinating whilst yet within the seed-vessel. The final cause or purpose of this singular provision is evident, when the circumstances under which the tree grows are considered. Were they to be shed as seeds usually are, they would fall into the water, and be carried by the waves of the sea, or by the currents of the rivers, on the margins of which they live, far from any place that is fitted for their growth. But by the long radicle perforating the seed-vessel, the seedling plant, when dropped, becomes fixed in the swamp; and thus forests of Mangroves are formed of vast extent, unsafe to be trodden by human foot, but over which the savage natives pass, leaping or climbing from root to root for many miles, without once daring to trust their weight upon the treacherous marshy ground. These swamps continually encroach on rivers, lakes, and seas; for the network of roots intercepts and collects all the solid matter brought down by the rivers; and, as a large part of this consists of decomposing vegetable matter, the Mangrove swamps are peculiarly unhealthy to human beings, who are very liable to suffer from pestilental fevers, if too long exposed to their emanations. When the roots of the Mangroves in such places are left bare by the ebb of the tide, they are seen to be covered with

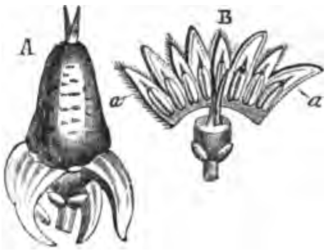

FIG. 157.—PARTS OF THE FLOWER OF MANGROVE. A, the fruit, seated upon a calyx of four sepals, and surmounted by two styles. B, a flower cut open, showing four petals alternating with four sepals, (the latter being hairy,) and eight stamens situated opposite to these; the pistil is left in the centre.

oysters and other shell-fish, which cluster around them; and hence originated the wonderful tales of the early voyagers in tropical climates, who affirmed that, in the East and West Indies, oysters, &c. grow upon trees. The properties of this order are astringent; and the bark of several species is used, in the countries where they grow, for dyeing black with iron.

599. The succeeding order, ONAGRARIACEÆ, requires notice chiefly on account of its containing several British species, among which may be mentioned the *Œnothera*, or Evening-Primrose, and the *Epilobium*, or Willow-herb. The former derives its common name from the circumstance of its beautiful yellow flower unfolding to the evening sun, but retiring with the glare of advancing day. Its scientific name, which means Wine-trap, was conferred upon it on account of the use formerly made of its roots, which were eaten after dinner (as olives now are) as an incentive to drinking; it was originally called *Onagra*, or Ass-food; and from this name, that of the order has been derived. Of the latter, a great many species exist in this country, some of which may be found in almost every hedge. They may be at once recognised by the peculiar position of the flower, which seems placed at the top of a long pod or seed-vessel, whence the scientific name (meaning *upon a pod*) is conferred upon it. One of the species of this, known as the *Great Hairy Willow-herb*, is among the finest of all our British herbs; its stout hairy stems rising to the height of five or six feet, and being terminated by long clusters of bright red flowers. The typical genera of this order may be at once distinguished, by the prevalence of the number *four* in *all* the parts of the flower. The calyx consists of four sepals, which adhere at their lower part, so as to form a long tube enveloping the ovarium; and they not unfrequently adhere in some degree, after they have diverged from the top of this, so that the calyx appears as if it were divided into only two portions. From the top of the tube of the calyx arise four petals; and within these are commonly found eight stamens, each of which has a very long anther, swinging (as it were) by its middle from the summit of the filament. The pollen of this tribe is peculiar in form, the grains being triangular, and cohering to

each other by delicate threads. The ovarium, which will be found altogether below the flower, is four-sided, and contains four cells, in each of which are a great many ovules; from this a single style arises, which mounts through the tube of the calyx, and usually separates at the top into four stigmas. The fruit is a dry capsule with four angles, separating into four valves. The seeds of the Willow-herb are remarkable for the curious provision by which they are dispersed; each of them has a very long tuft of silk at one end, which is so light, that the faintest breeze is sufficient to buoy it up and carry it to a great distance.

600. Although several handsome species of this order abound in Britain and in other parts of Europe, it is in America that it is most predominant; and from that continent we have derived a plant of far greater beauty than any native species, which is one of the most splendid of the foreign ornaments of our gardens during the summer and autumn. This is the *Fuchsia* (pronounced Fushia), which, although at first introduced as a greenhouse plant, is now extensively cultivated in the open air, in the southern parts of Britain, and in sheltered situations in the north. "Every body," it has been remarked, "has Fuchsias; the poor weaver grows them in his window; many an industrious cottager shows them as the pride of the little plot of ground before his door; and even the suburban inhabitants of London speak of the beautiful Fuchsias they rear, with enthusiasm and delight." The calyx of this genus is of a deep crimson; and the petals, which are of a dark purple, are small, and rolled up within it. The fruit differs from that common to the order, in being a berry with a juicy rind, formed by the thickening of the pericarp, instead of being a dry capsule. This order has little, except its beauty, to render it interesting to mankind; for there is not a single species which possesses any particularly useful property. The number of its stamens being invariably 2, 4, or 8, its genera are distributed, in the Linnæan classification, among the classes DIANDRIA, TETRANDRIA, and OCTANDRIA.

601. The next important order is that of MYRTACEÆ, the *Myrtle* tribe; in the flowers of many among which, also, we find

the number four predominating; but it is not the number characteristic of the group. The leaves of the Myrtle and its allies are characterised by the same structure as that which has been noticed in the Orange (§. 563), being studded closely with little receptacles, which contain a volatile oil; so that, if they be held up to the light, they look as if pierced with holes closed up by a green transparent substance; and if bruised they emit a fragrant aromatic odour. In the common Myrtle, as in most of the order, the calyx consists of five sepals, which adhere so as to form a tube; and within this, there is a corolla consisting of five small petals; the latter, however, is absent in some species. Within the corolla, we find a considerable number of stamens, inserted on the summit of the tube of the calyx; their number is generally a multiple of that of the sepals, and they are sometimes united into bundles. The ovary of the Myrtle is divided into three cells, each of which contains a good many ovules; on this is mounted a single style, which ends in a very small stigma. The fruit is a purple berry, very much resembling that of the Fuchsia; but it contains only three cells instead of four.

602. In some species, however, the ovary is only two-celled, whilst the parts of the flower are arranged in fours. This is the case in the *Caryophyllus*, a tree of which the unripe flower-buds are known as *Cloves*. This tree is a native of the Moluccas and other islands in the Indian Ocean, from which it has been transported to several parts of the continent of Asia, and also to the West Indies. It is only within a very limited range of climate, however, that the Clove acquires its full aromatic flavour, so as to be useful as a spice; for even when grown in some of the larger islands near the

FIG. 158.—BRANCH OF CLOVE TREE, WITH FLOWERS AND BUDS.

Moluccas and in Cochin-China, it is almost tasteless. The Clove has been known in Arabia from the earliest ages; and it was introduced into the European market nearly 2000 years ago. Up to a comparatively recent period, however, the source from which it was obtained was not known to Europeans. Early in the 16th century, the Moluccas were discovered by the Portuguese, and were soon afterwards taken from them by the Dutch, who endeavoured to monopolise the growth of the Clove, and to regulate the quantity which should be supplied, by cutting down or planting trees, according to their own supposed interests. This system more than once occasioned an insurrection among the natives, who regard the Clove-trees with great attachment, and who are in the habit of planting one at the birth of each child. Every part of the Clove-tree abounds with aromatic oil; but it is most fragrant and plentiful in the unexpanded flower-buds, in which it is so abundant that it may be pressed from them. It is one of the few essential oils that are heavier than water. It is a very powerful stimulant; and is sometimes employed in medicine; but its principal use is in cookery. The average annual crop of Cloves is from 2lbs. to 2½lbs. from each tree; but a fine tree has been known to yield 125lbs. of this spice in a single season; and as 5000 Cloves only weigh one pound, there must have been at least 625,000 flowers upon this single tree. The quantity imported into Britain in 1839 was upwards of 367,000lbs.

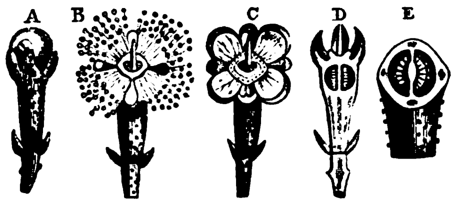

FIG. 159.—STRUCTURE OF FLOWERS OF CLOVE TREE. A, bud or Clove. B, the flower expanded, showing the stamens in four bundles. C, flower with stamens removed, showing the calyx and corolla, each consisting of four pieces. D, vertical section of ovarium. E, horizontal section of ovarium.

603. Several other species of this order have aromatic properties, and yield products which are valued as spices. This is the case with the Pimento, the berries of which are known under the name of All-spice, from being considered to unite the flavour

of cloves, cinnamon, and nutmegs. They yield an oil which much resembles that of cloves. The pleasant fruits called the Rose Apple and the Jamrosade of the East Indies, and the Guava of the West Indies, are the succulent berries of shrubs of the Myrtle tribe; as is also the Pomegranate, which was originally a native of Barbary, but has now migrated to Europe. The volatile oil of Cajeputi is distilled from the leaves of an Indian species; this has long been known as a valuable external application in rheumatism; and, for a short time, it enjoyed the reputation of being a specific for the Indian cholera. The leaves of another species are used by the Malays as tea.

604. There is a remarkable division of the Myrtle tribe, in which the fruit is dry, instead of being a berry, and opens at the top. The greater part of the species belonging to it are natives of New Holland; and amongst these may be specially mentioned the *Eucalyptus* or Gum-tree. This is destitute of corolla; and the calyx has the sepals adherent very closely together, so as completely to envelop the stamens. When these expand, however, the upper part of the calyx separates from the lower, and is carried off upon the top of the stamens, very much as in the Eschscholtzia (§. 525). The Eucalypti are distinguished for their astringency; and the tannin which they yield has been extracted from their bark, and used in the manufacture of leather. An Indian species affords an astringent extract, which has been substituted for Kino.

605. This order is almost entirely restricted to warm climates. A large number of species is found in South America and in the East Indies; whilst, of the latter division of the group, a considerable proportion exists in New Holland and the South Sea Islands. The common Myrtle of this country is a native of the South of Europe; and it is well known that this beautiful evergreen is liable to great injury, and even to be destroyed, if not carefully protected from the cold of our severe winters.

606. The order CUCURBITACEÆ, or *Gourd* tribe, is not a large one, but it contains several species which are highly useful to Man, such as the various kinds of Melon, Cucumber, Gourd, &c. These plants are all herbaceous, and grow by twining stems,

which are furnished with tendrils. The flowers are very frequently monœcious or diœcious; but they are sometimes complete. The calyx and corolla are usually small; the former (as in the Cucumber) is not unfrequently absent; and the latter in most cases assumes the appearance of a calyx. Their parts are five in number, as are also the stamens, which very commonly adhere into a tube inclosing the style. The ovarium consists of three or five carpels united together; these are enveloped by the prolonged receptacle or fleshy tube of the calyx (just as in the Apple, §. 595). The ovary, however, has only one cell, the partitions between the carpels having been obliterated; but in this single cell we may readily see, on cutting across a Cucumber, that the ovules are arranged on three lines which pass up the sides, and which are, therefore, parietal placentæ like that of the Heartsease. It is curious that, in the Melon and Cucumber, which are usually regarded as diœcious species, the development of staminiferous or pistilliferous flowers should be entirely governed by the degree of heat to which the plants are exposed; the former being produced when the proportion of heat to light has been considerable, and the latter under contrary circumstances. The plants of this order are almost entirely natives of hot climates, and can only be grown elsewhere under a considerable amount of artificial heat.

607. Although we are commonly accustomed to consider Melons and Cucumbers as quite free from injurious properties (except in causing indigestion in weak stomachs), this character does not extend to the whole order. The bitter purgative drug termed Colocynth is obtained from the pulp of a sort of Gourd, which is a native of the Levant, Arabia, &c.; and from the Momordica Elaterium, or Spirting Cucumber, a still more active preparation has been obtained, a few grains of which are so violent in their operation as even to destroy life. This bitter purgative principle is not absent in the common edible fruit, but is present in smaller proportion. Besides furnishing palatable food, this order is very useful to man in supplying him with vessels of various forms and sizes. Some gourds are nearly globular in form; and the rind, when the fruit is cut in half and the inte-

rior is removed, furnishes two basins. Others grow in the shape of bottles; and these sometimes attain the dimensions of six feet long by a foot and a half in circumference; when very young and small, they are made into spoons. Such vessels are known in the East and West Indies, Arabia, Egypt, &c., as *Calabashes*. Some of the fruits from which they are made, are as harmless as the cultivated Melon and Cucumber; but others contain much of the bitter purgative principle; and, in preparing the latter, it is requisite not merely to scoop out the entire pulp, but to allow water to stand in them, and to change this several times, till all the bitterness be removed from the rind. The common *Pumpkin* is remarkable for its rapid growth; in good soil, and well supplied with water, it will form shoots 40 or 50 feet long, and will cover an eighth part of an acre of ground in a season. Its pulp is eatable, but it is not much used in this country. On the Continent, however, it is frequently employed as an ingredient in various dishes; and it is extensively cultivated, for the purpose of feeding cattle and hogs, as well as on account of the seed, which yields an oil suitable both for food and for burning. The Vegetable Marrow, which within a few years has become a common dish, is the produce of an allied species of gourd. The Water Melon approaches in character to the Cucumber. Its fruit is so succulent that it almost melts in the mouth; and in warm climates or in hot seasons, is a most refreshing article of diet. To the Egyptians it may be said to be both food and physic. It often grows to a large size even in this country; but it is only between the tropics, that it attains its greatest dimensions; in Senegal, one has been known to weigh 60 lbs.

608. Very nearly allied to the Gourd tribe is the order PASSIFLOREÆ, or *Passion-Flower* tribe, which also consists of plants having creeping stems, supporting themselves by tendrils, and bearing large juicy fruit. This order is principally to be met with in America; and its name is derived from the superstitious fancies, entertained by the Spaniards who discovered that continent, respecting the flower, which they considered to be an allegorical representation of the crucifixion and sufferings of our Saviour. In its anthers, they saw his five wounds; in the three

styles, the nails by which he was fixed to the cross; in the column which rises from the bottom of the flower, the pillar to which he was bound; and a number of little fleshy threads which spread from its cup, they compared to the crown of thorns. It seems difficult to imagine how such a notion could have been suggested to them; since the general aspect of the flower does not appear such as to be likely to excite it. Various species of Passion Flower are now naturalised in this country; and are beautiful ornaments to the fronts of houses, garden walls, or trellis-work, over which

FIG. 160.—BRANCH OF PASSION-FLOWER.

they may be trained. They sometimes climb to the tops of high trees, and hang down in elegant festoons from their branches. On examining the flower, we find that the calyx has five sepals, which are usually green on the outside, but are yellow, red, blue, or purple in their interior. The petals are equal in number to the sepals, and are of the same colour with their inside; sometimes, however, they are absent. Next within these, we do not at once come, as we might expect, to the stamens; but we meet with several rings of beautiful fleshy threads, which spread from the calyx like rays, and are splendidly variegated with crimson or blue-and-white. These diminish in size towards the centre of the flower; and at last lose themselves, as it were, in some little rings, that surround the base of the column, which now presents itself in the centre. These threads are to be regarded either as stamens or petals in an undeveloped state; it is

of no consequence which we denominate them.

FIG. 161.—A, SECTION OF PASSION-FLOWER. B, CENTRAL COLUMN, showing the three styles at the top; the five anthers, *a*, *a*; the tube, *b*, *b*, formed by the cohesion of the filaments; *c*, the innermost ring of the undeveloped petals; *d*, the origin of the petals; *e*, the origin of the calyx.

In the centre of the flower, from the bottom of the calyx, rises a column; at the top of which we observe five anthers. The column itself, of which the outside resembles in colour the surrounding bodies, consists of an exterior sheath, formed by the adhesion of the filaments to each other, and of an interior solid stalk, on the top of which the ovary is mounted. The ovary, when cut across, is found to consist of but one cavity; the ovules, however, are attached to three parietal placentæ (as in the Violet), showing that the seed-vessel is composed of three carpels; and the summit of the ovarium bears three short styles, which terminate in thick swollen stigmas. The fruit is a fleshy egg-shaped body, containing a number of pulpy seeds; but it varies extremely in size and colour, in the different species. In all instances, however, it is destitute of any injurious principle, and may be eaten with safety. In the common Passion-flower, it is about as large as a hen's egg, and orange-yellow on its exterior; in some tropical species, called *Grenadillas*, it is much larger, attaining the size of a man's head, and is greener in its colour. These are cultivated on account of the slightly acid pulp they contain, which renders them refreshing; and the rind, which is also a little acid, is cut into slices and made into tarts, which have somewhat the flavour of those made of apples. The substance which surrounds the seeds is not mere pulp, but is a sort of fleshy coat, termed the

arillus, which gradually rises from the bottom of the ovule, and at last envelops it completely. It will hereafter be seen that the spice known as *mace*, is the arillus of the nutmeg. A species of Passion-flower inhabiting the Isle of France is remarkable for the narcotic properties of its root; but it is not unlikely that these are shared in some degree by others.

609. Passing over several small orders, we come to that of CRASSULACEÆ, the *House-leek* tribe, which is chiefly interesting as containing several British species of succulent plants, which flourish under circumstances that would be fatal to almost all others. They are found in the driest situations, where not a blade of grass nor a particle of moss can grow, on naked rocks, old walls, sandy hot plains, alternately exposed to the heaviest dews of night, and to the fiercest rays of the noon-day sun. Soil is to them a means of keeping them stationary, rather than a source of nutriment. In this respect they resemble the Cacti and other plants of tropical climates, which they represent in more temperate regions. About half of the species known to Botanists are natives of the Cape of Good Hope; and nearly half the remainder are European plants. Although they resemble the Cacti, and some other orders, in the succulent nature of their stems and leaves, there is no other very close correspondence between them. The number of parts in the flower is subject to great variation. The calyx may consist of from three to twenty sepals, which are united at the base. The petals are equal in number to the sepals, and are inserted into the calyx; they are sometimes distinct, and sometimes cohere into a monopetalous corolla. The stamens are either equal in number to the petals, alternating with them; or are twice as many, in which case those alternating with them are longer, and come to maturity earlier, than the others. The carpels are equal in number to the petals, and are opposite to them; they are arranged in a circle, and are more or less adherent in different species, each having its own style and stigma. Every one contains several ovules, which are arranged in two series along its internal edge, where the dehiscence or opening usually takes place at the time of maturity. The *Sedums* or Stonecrops, of which many species

exist in Britain, belong to the Linnæan class and order DECANDRIA *Pentagynia*, having five parts in the calyx, corolla, and ovarium, with double the number of stamens; whilst the *Sempervivum*, or House-leek, is found under DODECANDRIA *Dodecagynia*, having twelve stamens and twelve styles. The common British species of the latter is remarkable, for almost always bearing ovules on its anthers, instead of pollen. These plants are not only very tenacious of life when naturally exposed to the elements, but resist efforts made to destroy their vitality, when it is desired to preserve them. The collector finds it very difficult, therefore, to prepare them for his Herbarium; for they will push long shoots whilst under great pressure, and after being submitted to a high temperature. It is from the deficiency of stomata, and the thickness of the cuticle, that it is so difficult to dry them; and it is obviously by these properties, that they are enabled to resist the rays of the sun.

610. The order CACTEÆ, or *Prickly Pear* tribe, is by nature exclusively confined to the New World; but several species have now been naturalised elsewhere. They do not, even on that continent, extend far from the tropics; they frequent hot, dry, exposed situations, like those to which the Crassulaceæ are adapted. Most of the species of this order are remarkable for the absence of leaves, of which no other traces are found, than tufts of prickles arising at regular intervals from the stem,—these being the veins of the leaves, between which the parenchyma is not developed (§. 236).

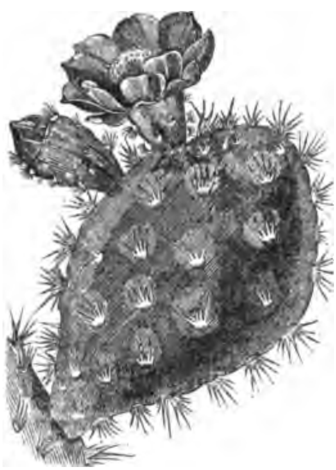
FIG. 162.—STEM, BRANCH, AND FLOWER OF CACTUS.

The stems and branches are very fleshy and succulent, and usually have flat expanded surfaces, which in some degree per-

form the functions of leaves. In the various species of Cactus, however, we find the form of the stem differing greatly. Thus in one kind, known as the Melon-Cactus from its form, the stem is so much stunted as well as expanded, that it quite resembles the fruit alluded to. In other species, however, the stems are round and greatly prolonged, resembling ropes; whilst in others, again, they are equally long, but are angular. All are adapted to the same circumstances of growth; but the Melon-Cactus, from its greater bulk, in proportion to the surface it presents, can exist in the most exposed situations. It usually happens in tropical climates, that, during a certain portion of the year, a large quantity of rain falls, the atmosphere is loaded with dampness for many weeks, and the soil is completely saturated with water. During this time, the Cactuses live very fast, and distend all the cavities of their tissue with fluid. The resistance afforded by their thick cuticle, and by the deficiency of stomata, to the evaporation of this, enables them to retain a store of it (as the Camel holds water in the stomach) until they can acquire a fresh supply. At other times, they may be said to live very slowly; the functions of exhalation, digestion, &c., are performed very inactively; and the fluid which they have absorbed during the rainy season is adequate for their support, during all those months when they cannot live upon the soil or the atmosphere. This property sometimes renders the Cactus tribe of great utility to man. On Mount Etna, for example, and its volcanic fields, it is the *Indian Fig* which the Sicilians employ, to render such desolate regions susceptible of cultivation. This plant readily strikes into the fissures of the lava, and soon, by extending the ramifications of its roots into every crevice of the stone, and bursting the largest blocks asunder by their gradual increase, makes it capable of being worked. The juiciness of the stems causes them to be sought in the West Indies, during dry seasons, by the cattle; which, tearing off the thorny integument that covers them, feed upon the moist pulp within.

611. The flowers of this tribe are commonly very showy; and the number of handsome species, which have been of late introduced into our hothouses, gives them an air of splendour

unknown until recent years. No distinction can be traced between the calyx and corolla; for the flowers branch off directly from the stem, and its cylindrical axis is covered with scale-like coloured bracts, which at the upper part gradually pass into thin delicate petalline leaves, which unfold, tier after tier, from within each other, adhering by their lower ends so as to produce a firm fleshy tube. From the interior of this tube, spring a number of rows of slender stamens. The ovarium is situated in a cavity within the apparent stalk of the flower; and contains a considerable number of ovules, attached to parietal placentæ. The style is a single column, springing from the top of the ovarium; and, after rising above the anthers, it divides into a star-shaped set of stigmas, equal in number to the placentæ. The beauty of the flowers is usually very short-lived; some of them only last for a few hours. One of the most splendid species is the *Cereus grandiflorus* or night-blowing Cereus, the blossoms of which begin to expand about 6 or 7 o'clock in the evening, and are fully blown about midnight; but, by 3 or 4 in the morning, they are quite decayed. During its short continuance, however, there is scarcely any flower of greater known beauty. The perianth, when open, measures nearly a foot in diameter; the outer leaflets are of a dark brown colour, the inner ones are of a splendid yellow, gradually shaded, toward the centre of the flower, into a pure and brilliant white. When several of these magnificent flowers, therefore, are open at once upon a single plant, they seem like stars shining out in all their lustre, verifying the poet's declaration that

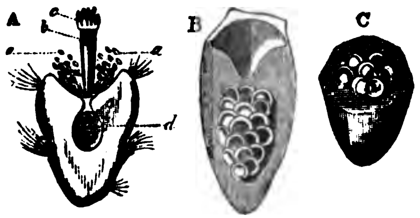

FIG. 163.—PARTS OF FLOWER OF CACTUS TUNA. A, thickened axis, bearing the Stamens, *a*,—the style, *b*,—and stigma, *c*; and enclosing the ovarium, *d*. B, vertical section of ovarium. C, transverse section of ditto.

> "Darkness shows us worlds of light
> We never see by day."

Besides possessing beauty for the eye, these flowers are delightfully fragrant, and fill the air with odours to a considerable distance around.

612. When the flower has withered, the ovary enlarges and becomes pulpy, and is in time converted into a fruit which has much resemblance to that of a gooseberry, but is usually inferior in flavour. The juiciness of the fruit of many species, however, renders them acceptable in warm climates; on Etna, for example, the large cooling fruits of the Indian Fig are sold in considerable quantity, and some of the varieties are of great excellence.* Independently of this use, the Cactus tribe cannot be said to be of any direct advantage to Man; they indirectly serve him, however, in a very important manner. Several species of the order are infested with insects of the genus *Coccus*, some of which, especially the *Coccus Cacti*, become, from the colouring matter they collect from the fruit and flowers of the plant, of great commercial importance, being, in fact, the *Cochineal* of the painter and dyer. One particular species of Cactus contains a red juice more delicate than the others; and it is when feeding on this, that the bodies of the Insects acquire the most brilliant tinge. Cochineal consists of nothing else than the dried bodies of the Insects, which are impregnated throughout with this colour.

613. The next order to be noticed is that of the Grossulariæ or *Gooseberry* tribe, which is nearly allied, in the structure of its flowers and fruit, to the Cacteæ, and may be regarded as representing that order in cold climates. Although the stems of this tribe are not succulent, nor their leaves entirely deficient, yet there is a conversion of many leaves into spines, by the absence of their fleshy part. If the flower of the common Gooseberry or Currant be examined, the following will be found to be its structure. The calyx is a little globular cup, green without and purple within; its border is marked by five

* It will serve to show the remarkable combination which exists between different organs in this order, to state that the Author has witnessed an instance in which the *fruit* of a Cactus sent forth a regular branch, which exactly resembled those proceeding from the stem.

indentations, which show it to consist of five sepals. At its mouth are five small scales, which are the petals; and between these are the stamens, which are also five in number. In the centre of these will be seen a single style, cleft at the top into two small stigmas; and these arise from an ovary which is situated below the calyx, imbedded, as it were, in the flower-stalk, very much as in the Cacteæ. The ovary is one-celled, and contains a considerable number of ovules, arranged upon two parietal placentæ. When the flower has withered, the ovary swells, and becomes filled with a pulpy substance which surrounds the seeds; it is by the remains of the calyx, that what is known as the *eye* of the gooseberry is formed. If a ripe Gooseberry be divided into two parts from its point to its base, the position of the seeds, and their attachment by threads to its walls, will be seen to correspond with what has been said of the structure of the ovarium.

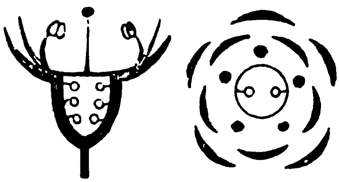

FIG. 164.—DIAGRAM OF FLOWER OF GROSSULARIÆ.

614. The description just given of the flower of the common Gooseberry is not entirely applicable to every species; for in some the petals are entirely absent; and in others, the calyx is brilliantly coloured, as in the Fuchsia. Currants, as well as Gooseberries, belong to this order; indeed, the botanical difference between the two is extremely slight. These fruits only attain their true perfection in temperate climates; and it is probable that they are nowhere produced of equal size and flavour to those which are raised in Britain. It is not uncommon for them to attain the weight of from an ounce to an ounce and a half. In Spain and Italy, the heat of the summers is too great for the due development of the fruit; these plants not being provided, like the Cactus tribe, with the means of resisting it. All the different kinds of Gooseberry are varieties of one species; and the same may be said of the Red and White Currant; but the Black Currant is a distinct species, of which no varieties

have been obtained. The latter grows wild in Russia, where the juice of its berries is made into wine; and in Siberia the leaves are used as tea.* Various species of this order are found in North America; and some are particularly abundant on the mountains of Northern India, giving quite a European character to that region.

615. The succeeding order, SAXIFRAGEÆ, or *Saxifrage* tribe, chiefly deserves notice on account of the number of species it contains, which present themselves in cold and mountainous countries, occupying the sides and even the summits of lofty hills, the tops of walls, the depths of wooded dingles, the sides of trickling streams, and even the recesses of the most dreary bogs. Their flowers are remarkable for their exquisite neatness, and for the purity of their colours. One of the best known species is the *London Pride*, which, although a native of the Yorkshire and Irish mountains, endures without injury the smoke and impure air of the metropolis; from which circumstance it derives its name. It is met with in cottage gardens, almost as frequently as are daisies and primroses. The *Hydrangea* is another species cultivated in gardens; and this is remarkable for the circumstance of the showy part of the flower consisting really of bracts. The calyx, in the *Saxifrage* tribe, usually consists of five, rarely four, sepals, more or less adherent to each other and to the ovarium. The number of the petals, which are seldom wanting, is ordinarily equal to that of the lobes of the calyx; and that of the stamens is either the same or double. The ovarium usually consists of two carpels diverging at their apex; the partition between these is sometimes complete, forming a two-celled ovarium; but occasionally absent when it is one-

FIG. 165.—DIAGRAM OF FLOWER OF SAXIFRAGEÆ.

* The Gooseberry as well as the Red and Black Currant, are indigenous to this country.

celled. The styles are commonly distinct, but are sometimes adherent; in the greater number of the tribe there are no more than two, indicating that the ovarium is made up of but two carpels. Each cell contains a large number of minute ovules. The fruit is ordinarily enclosed in the calyx, and opens only at the point. There is one genus, however, in which there is no adhesion between the calyx and ovarium; and there are several in which the adhesion does not extend far up. In habit this tribe a good deal resembles some of the Rosaceæ.

616. The plants of this order are almost universally diffused over the globe; but they cannot be said to be of any direct utility to Man. The name of the principal genus, *Saxifrage*, however, is probably derived from the power which may be attributed to the plants composing it, of breaking up the surface of the rocks on which they grow, by insinuating their roots into crevices, and afterwards causing them to distend in the same manner as the Cacteæ have been just now stated to do (§. 610). If this idea be correct, it is obvious that their function, in preparing the surface of barren rocks and mountain sides, for the habitation of plants of a higher order, is one of the most important in the whole economy of nature. At least twenty species of this genus alone exist in Britain; and some or other of them are found in almost every rocky or exposed situation. To this order belongs the very singular genus *Parnassia* (so named because it is said to abound on Mount Parnassus), the British species of which is the companion of the Sun-dew in its marshy haunts, and rivals it in singularity of structure. In the latter, the peculiar glandular hairs are found only on the leaves; but in the Parnassia they exist on the flowers. Alternating with the stamens, there are five fleshy scales, divided at their edge into numerous rays, each of which is tipped with a beautiful pellucid greenish gland; so that the flower, when viewed from above, appears set with sparkling jewels. The *Hydrangeas*, (which are not natives of Britain, but have been introduced from China and Japan,) are also marsh plants, and should be kept well supplied with water, when grown in gardens. A full-sized plant requires as much as from 10 to 12 gallons daily in

warm weather. When the floral envelopes are over-developed by cultivation, the flowers become barren, and the plant must be propagated by cuttings. They grow in closely-set clusters; and a little examination of one of these will often disclose many curious irregularities, produced by the partial union of two or more flowers, arising from the want of room for their full development. The regular number of the large coloured leaflets is four; but not unfrequently we find a flower possessing five, six, seven, eight, or even more; and the additional ones are easily shown to be derived from other flowers, which are partially *fused* or melted down, as it were, into the first. The Hydrangeas are likewise remarkable for the varieties of colour to which the same species, or even the same individual, is subject, according to the soil in which it grows. Their natural and most common colour is red; in a poor soil, however, they become of a dingy green; but when grown in richer mould, especially in peat-earth, and watered with an alkaline solution, or manured with wood-ashes, they assume a rich blue tint, and their clusters increase in size and present a very handsome appearance.

617. We next come to an order of great extent and importance; and one that is marked by an evident peculiarity, which enables us to distinguish very readily, in almost every instance, the plants that belong to it. This is the order UMBELLIFERÆ, the *Umbelliferous* tribe, so named from the peculiar arrangement of the flowers upon the stem, which pervades the whole group. If we look at a plant of any common species, such as the Parsley or Hemlock, we observe that the flower-stem divides at the top into a number of short slender rays, which all proceed from one point, just as do the stretchers of the umbrella. If the flowers were borne on these, the whole set would be considered as forming a *simple umbel*, such as we find in the Geranium and many other plants. But in the Umbelliferæ, we commonly find that each stalk of the umbel subdivides again, bearing a second set of rays that carry the flowers at their extremities, which itself constitutes an umbel. The whole system is then termed a *compound umbel;* and it is this which is characteristic of the order. It may be further noticed, that the stems are

almost always hollow, and that the leaves are usually much divided.

618. The separate flowers are generally very minute, and require good sight, or the aid of a magnifying-glass, for their parts to be distinguished. The calyx generally appears very small, seeming to consist only of a little narrow border, from within which the petals arise. This border is marked, however, by five indentations, showing that it consists of five adherent parts or sepals; and these adhere not only to each other, but to the ovarium (which is consequently inferior), so that their points only are free, and these seem to spread out from the summit of the seed-vessel. The petals are five in number, and spring from the top of the tube of the calyx; between these arise five stamens. In the centre of the flower we observe two styles; and these arise from the top of the ovary, which is two-celled, each cell containing a single pendulous ovule. These characters are so constant, that very nearly the whole of the order is contained in the Linnæan class and order PENTANDRIA *Digynia;* the only exception being in a few species, in which the ovarium is made up of *three* carpels. As the fruit ripens, the seeds become adherent to the walls of the ovary; and the two divisions of the latter separate from one another; so that for the ripe fruit, we find two grains, which seem like seeds, and are commonly considered as such, although really consisting of the carpels enclosed in the tube of the calyx. They are frequently marked in a curious manner on the outside, by ribs or nerves which belong to the latter; and it is in the substance of this envelope, that the little receptacles of secretion exist, which contain the essential oils that are characteristic of the grains of this order, such as those of Anise, Carraway, &c.

619. The strong general resemblance which exists between Umbelliferous Plants, makes it frequently a matter of some difficulty to distinguish their various genera and species. This is the more to be regretted, as there is a great difference in their respective qualities, some being nearly or quite harmless, whilst others are virulent poisons. The Carrot, Parsnep, Celery, Fennel, Parsley, Carraway, Dill, Anise, Coriander, and Sam-

phire, are all well-known kinds, which are useful for various purposes,—the three former being very largely cultivated, as affording important articles of food; whilst, on the other hand, the group contains the Hemlock, Cowbane, Dropwort, Fool's-Parsley, and many other species, which are more or less unwholesome. The fact is, that the general character of the order is to possess narcotic and acrid qualities, which are especially abundant in some species, and which probably exist, in some degree or other, in all. In regard to the Carrot, and Parsnep, the same remark applies, which has been formerly made (§. 659) respecting the Potato; that the edible portion consists principally of starchy matter deposited for the nutrition of the growing parts, and that this is consequently free, or nearly so, from the peculiar properties which characterise the order. The Celery, when growing in its usual manner, possesses these properties in a degree which would render it injurious as well as disagreeable to the taste; and it is only by being blanched (§. 288) that it is rendered palatable and wholesome. The Fennel and Parsley, of which the leaves are employed to flavour various articles of cookery, are by no means devoid of injurious properties, though the small quantities in which they are usually eaten do not cause them to be manifested; the latter is said to be much more injurious to Parrots, than it is to Man or Cattle. These properties are generally contained in the leaves and stems alone; and consequently the fruits of even the poisonous species are for the most part destitute of them, and may be used as aromatics.

620. Of the British species, the only one of which the juices are ordinarily used for medicinal purposes is the *Conium maculatum*, or Hemlock, which derives its specific name from the spotted appearance of its stems, by which it is easily recognised. Although the order is more abundant in temperate climates than between the tropics, there are certain plants of warm climates which afford medicinal products of great value, known under the name of the *fœtid gums*. They are of the nature of Gum-resins (§. 378), and are distinguished by their powerfully disagreeable odour. Those most in use are Assafœtida and Galba-

num, which are procured from Persia and the East Indies, and are remedies of great utility in hysteric and spasmodic complaints. The geographical distribution of this order presents some points of much interest. Out of about 900 species, which it was estimated some time ago to contain, nearly three-quarters are inhabitants of the Northern Hemisphere; and of these, by far the larger proportion belongs to the Old World. In the whole of America there are but about 160 species; whilst in the extensive wastes of New Holland, and in the numerous islands of the Polynesian Archipelago, only about 70 are known. The number in Britain alone is not less than 66.

621. The order LORANTHACEÆ or *Misseltoe* tribe may be next briefly noticed, chiefly on account of the curious habits of the numerous species it contains, which are nearly all parasitic upon other plants; forming, like the Misseltoe, natural grafts with them, by insinuating their roots into their chinks, and deriving from them the supply of sap afforded by the ascending current (§. 320). The calyx of their flowers is adherent to the ovarium, and scarcely exhibits any trace of division into sepals; its tube is enclosed at its base between two bracts. The corolla is formed of from 3, 4, or 8 petals, more or less united at the base. The stamens are equal in number to the petals, and are opposite to them; their filaments are usually adherent to the petals; but sometimes they are absent, so that the anthers are seated, as it were, upon the latter. The ovarium is one-celled, and contains but a single pendulous ovule; there is only one stigma, and the style that should support this is sometimes absent. The fruit is a berry, containing a viscid matter, like bird-lime; it is frequently eaten by birds, which drop the seed on the trees on which they perch; and this, by the peculiar direction of its germination (§. 321), insinuates its radicle into their stems or branches.

622. The principal genera of this order are the *Viscum* and the *Loranthus*. The former only inhabits Britain, and is known as the Misseltoe; it is generally found parasitic upon trees of the order Rosaceæ, such as the Hawthorn and the Apple; and it rarely occurs on the Oak. Hence it probably was, that, when

growing on the latter tree, it was held in superstitious veneration by the Druids of old. The Loranthus, on the other hand, infests a great variety of trees, each of these having, for the most part, a particular species which grows on it alone. Above 250 species of it are known; and these are mostly found in the tropical parts of America and India. In Africa, and in the South Seas, they appear to be very rare.

623. The next order, CAPRIFOLIACEÆ, or *Honeysuckle* tribe, bears a nearer relationship to the foregoing, than might have been suspected. The flower chiefly differs from that of Loranthaceæ in the stamens being alternate with the petals, instead of opposite to them; and the ovarium frequently (but not always) contains more than one cell. The order differs, also, in the absence of parasitic habits. To this group belong not only the Honeysuckle but also the Elder, and, in the opinion of some Botanists, the Ivy; as also the Guelder-Rose and Laurestinus, the latter of which is a beautiful garden shrub, bearing leaves and flowers all through the winter. All these plants are natives of the northern parts of Europe, Asia, and America; they are less abundant as we approach the tropics, and are almost unknown in the southern hemisphere. The flowers and leaves of most of this order are strongly odoriferous; the former are generally very fragrant; but the latter are frequently (as in the common Elder) fœtid, and possessed of acrid properties. The bark is generally astringent; that of some species has been used for tanning; and that of others has been employed in medicine for the same purposes, and with similar effects, as Peruvian Bark. The berries of the Elder and of other species contain a good deal of sweet juice, which may be fermented into a kind of wine. Those of an American species, when dried and roasted, furnish the best of all substitutes for Coffee, which is afforded by a plant belonging to the succeeding order. Another species, known as the Snow-berry, is cultivated in gardens on account of the delicate white colour of its fruit.

624. The next order, RUBIACEÆ, or *Madder* tribe, is a very extensive one, but is almost entirely confined to tropical countries. It comprehends the meanest weeds and the noblest flowering

trees,—obscure herbs with blossoms which it almost requires a microscope to detect, and bushes whose scarlet corollas are many inches long; and includes a plant which affords one of the most grateful beverages that the luxury of Man has prepared, with others of nauseous and bitter taste, some of which in skilful hands, are most valuable medicines. The Rubiaceæ, excepting the section which contains the Madder and its allies, possess stipules at the base of the leaves; of which the last order are destitute. The calyx consists of a cup, enclosing the ovarium, and scarcely divided even at its edge. The petals of the corolla are adherent at their lower part into a tube; their number is usually five, but varies from 3 to 8, as does also that of the sepals. The stamens are equal in number with the lobes of the corolla, and are alternate with them; they are generally adherent to the lower part of the tube. The ovarium usually contains two, sometimes many cells; the style is single, but is divided at the top into a number of stigmas equal to that of the

FIG. 166.—COFFEE PLANT, showing the flowers and berries, and the stipules at the base of the leaves.

FIG. 167.—PART OF THE FLOWER OF COFFEE PLANT. A, calyx inclosing ovary, with bifid style. B, tube of the corolla cut open, showing the five divisions of its upper part and the five stamens arising from it.

cells. The fruit is commonly a berry containing several seeds, inclosed in a fleshy covering; or it may be a hard capsule merely; or only one seed may have ripened, which is inclosed in a flesh, forming a *drupe*, like the Plum. The albumen of the seed is of a horny texture—a peculiarity that is well exhibited in Coffee, which consists of the seeds divested of their envelopes.

625. Coffee might be obtained from several species of the genus *Coffæa;* that derived from one, however, is so superior to the rest, that it alone is commonly cultivated; and numerous varieties of it, depending in part upon soil and climate, are now known. The native country of the Coffee Plant is Arabia; and the use of its seed as a nourishing and agreeable beverage, has been traced to a remote period, having been certainly common in Persia as far back as the year 875. Coffee was not introduced into Europe, however, before the year 1517; and it was a century and a half before it came into general use, even in the capitals, where Coffee-houses were established. The seeds were at first sold at an exorbitant price,—as much as four or five guineas the pound. The plant was introduced into the West Indies by Louis XIV., from a specimen presented to him by the Dutch, in 1714, of which he sent offsets to Surinam, Cayenne, and Martinique; and from this all the present plantations are descended. The East India plantations were derived from a similar common source,—a plant in the Botanic garden at Amsterdam, which had been raised at Batavia, from seed procured from Mocha, in 1690. The Mocha berries are smaller, and possess a higher flavour, than those which are brought from the West Indies. This is partly due to the difference of soil and temperature, and partly to a difference in the mode of culture. It would seem as if nearly the same quantity of the aromatic product were formed in each case; but that, in the large seed it is diffused through a greater quantity of the tasteless albumen, and is therefore less intense. It has been confidently asserted that, if the West Indian Coffee be kept for several years, instead of being roasted and consumed as soon as it can be transported across the Atlantic, its flavour improves, and becomes equal to that of the best Mocha.

626. The Coffee-tree grows erect, with a single stem, to the height of about 8 or 10 feet, and has long undivided slender branches, not unlike those of the bay-tree. The blossoms are white, and are seated on short footstalks, altogether resembling the flowers of the Jasmine. The berry is red, resembling a cherry, and having a pale, insipid, and somewhat glutinous pulp, inclosing two hard nearly hemispherical seeds, of which the flat sides are opposed to each other; the seeds are enveloped in a membrane, which resembles that forming the divisions of the core of the apple, and is called the parchment. The trees begin to produce berries when they are two years old; and in their third year they are in their full bearing. The blossoms expand very rapidly,—those of a whole plantation sometimes coming out in a single night, but they fade almost as rapidly. The pulp is separated from the berries, when these have ripened and have been gathered, in various ways. By some the berries are exposed to the sun, until they are perfectly dry, and the hardened pulp forms a husk, which is broken away with rollers. By others, the berries are exposed to the sun in layers, so that the pulp is caused to ferment. And by others, again, this is rubbed off in a sort of mill. The seeds, before being roasted, are nearly tasteless; but during this process, a change seems to take place in the chemical arrangement of their particles, which produces the aromatic flavour and odour so highly valued.

627. When Coffee was first introduced into Turkey, the use of it was forbidden by the government, on the ground of its being an intoxicating beverage; and the ministers of religion complained that the people forsook the mosques and crowded to the coffee-houses. It has since become, however, quite a necessary of life in Turkey; so that at one time the refusal of a husband to supply his wife with a reasonable quantity of it, was reckoned amongst the legal causes for a divorce. The history of the present large demand for it in this country is very remarkable. In 1808, when the duty on coffee produced in British plantations was two shillings a pound, it was beyond the reach of the poorer classes of consumers. The total quantity consumed in Britain was then little more than one million pounds,

from the importation of which the Government derived a revenue of about £160,000. But in 1824, the duty was lowered to sixpence a pound; and the consumption has gradually increased to more than 28 million pounds, producing an import duty of £900,000. There are strong reasons of a moral nature for encouraging the consumption of Coffee, by cheapening its price to the lowest amount; for it has been satisfactorily shown that the more extended use of it has mainly contributed to promote improved habits amongst large classes of the community.

628. The order Rubiaceæ takes its name from the *Rubia* or Madder plant, which furnishes the most important of our crimson dyes (§. 392). It is only in tropical countries, however, that it presents its finest aspect; but in some of these it is so predominant, that its species constitute about 1-29th of the whole number of flowering plants. Amongst the most important of these are the *Cinchonas*, which furnish the Peruvian or Jesuits' Bark so largely used in medicine. This is very astringent, and might be used for tanning; but its chief peculiarity consists in containing a large quantity of an alkaline substance termed *quinine*, which may be extracted from it by chemical means, and which, being the most valuable part of the drug, is now usually given in a pure state. This is almost a specific for agues; and is extremely valuable as a tonic in weakened states of the system. The Cinchonas, of which the several species afford this product in varying degrees, grow in extensive forests in South America; chiefly inhabiting the sides of the range of the Andes, between 10° North Lat., and 22° South Lat., and sometimes rising on these mountains to the height of 10,000 feet. It is from the trees growing in elevated situations, that the best bark is derived. Another most valuable remedy afforded by this order is Ipecacuanha, which is the powdered root of a little creeping-rooted, half-herbaceous plant, found in the damp shady forests of Brazil. This is chiefly employed in medicine as an emetic, and also to produce perspiration; but it has several other important uses.

629. Passing over several orders of secondary importance, we come to one alike remarkable for its peculiarities of structure, for the large number of plants contained in it, and for the variety of

size, colour, properties, &c., which these exhibit. The order alluded to is that of COMPOSITÆ or *Composite* plants, so named on account of the manner in which a number of flowers are clustered together so as to form one which is apparently single. We are in the habit of speaking of the Daisy, the Dandelion, the Sun-flower, the Dahlia, &c., as single flowers; and yet every one of these is really composed of a *head*, on which a large number of blossoms are crowded together. If any one of these be examined in its natural state (that is, not affected by cultivation), it will be found to consist of the following parts. In the first place, the flower-stalk spreads out into a large fleshy expansion, which is the disk or receptacle of all the florets united. Around the edge of this, we notice a whorl of small green leaflets; these are bracts, and the whole circle is termed the *involucrum*. Above and within these, we notice one or more whorls of flat leafy-coloured organs, which at first sight appear to be single petals, but which will be presently shown to be so many distinct florets, of which the corolla has expanded itself on one side only. In the wild Daisy and Sunflower, only one whorl of these exists; but in the cultivated Daisy, as in the Dahlia, they become numerous, from a cause that will immediately appear. Within these we find, crowded together upon the disk, a large number of minute flowers, scarcely having any perianth. That these are really such, can often be only distinctly seen with a magnifying glass. Every common Daisy of our meadows contains between two and three hundred such florets, each perfect in itself, that is having its corolla, stamens, pistil, and fruit. These central florets are termed *florets of the disk;* in them the floral envelopes are but little developed, whilst the organs essential to reproduction are complete. On the other hand, the flat leaflets by which they are surrounded are called *florets of the ray*, from the radiating manner in which they are set on the receptacle; in them, the corolla is developed at the expense of the reproductive organs, one or both sets of which are usually absent. If one of them be pulled up carefully at the end by which it was fastened to the flower, it will be seen that it is not flat at the bottom, as it is at the top, but that it becomes

tubular; and that a little thread ending in two horns, issues from the tube; this thread is the forked style, the stamens being here deficient. The coloured perianth in both these classes of flowers is evidently to be regarded in the light of a corolla; where, then, is the calyx? In the Daisy none is to be found; but in the Dandelion and many other Composite plants, we may observe that, on rooting up each floret from the receptacle, a few little narrow hairy scales are attached to their lower end, forming a sort of down; and this down or *pappus* is the only representative of the calyx. We shall presently see that, where it is present, it has an important function to fulfil. Below the pappus is the ovary, which is one-celled, and contains but a single ovule. The corolla of the florets of the disk is tubular from the bottom to the top; at the top it widens, and is cleft into five little divisions, indicating that it consists of five adherent petals. The style terminates in two stigmas, which project beyond the mouth of a little hollow cylinder, that is found at the orifice of the flower. This cylinder, when examined with a magnifying glass, is found to consist of the anthers, which adhere together, side by side, so as to form a tube; in other respects their structure does not differ from the usual character of these organs. The nature of this cluster of flowers may be better understood, by comparing it with an umbel, of which the radiating stalks have not been developed, so that the flowers which should be borne on them are all crowded together at the summit of the flower-stalk, from which these branches would have arisen. The fruit of each flower is a little grain, looking like a seed, but really consisting of a seed enclosed within the ovary. When the downy calyx exists, it remains attached to this, and forms a feathery plume, by which it is wafted through the air; and thus the seed is diffused and scattered by the wind. Every child who blows the delicate feathery balls of the Dandelion, thus assists in the multiplication of the plant; which it is very difficult to eradicate, when once it has gained a footing in a neglected garden, on account of this curious provision.

630. This order is one of very great extent, containing many thousand species; and it is desirable to state its principal sub-

divisions, as these may be recognised by examining the commonest British species, as readily as may the characters of the order itself. Such florets as exist in the ray of the Daisy, Marigold, &c., are technically called *ligulate* or strap-shaped, from their flattened aspect. Now in the Dandelion it will be found that both the ray and the disk are composed of ligulate flowers, to the entire exclusion of the tubular ones; such plants are ranked in a group named *Cichoraceæ*, from the common Cichory or Succory, with which they all agree in possessing a milky juice; and this, when concentrated, is found to have narcotic properties. This group contains a large number of our wild flowers.

FIG. 168.—COMPOSITE FLOWERS; A, CORYMBIFERÆ; B, CICHORACEÆ.

FIG. 169.—COMPOSITE FLOWERS; A, CORYMBIFERÆ; B, CINAROCEPHALÆ.

From these will easily be distinguished the group of *Cinarocephalæ* or Thistle-headed plants, which have, like the Thistle, a head of flowers, composed entirely of tubular florets, and of an almost hemispherical form; these are further distinguished, for the most part at least, by their hard and spiny leaves. To this section belongs the *Artichoke*, which is cultivated for the table, on account of the fleshiness of the scales or bracts, which form the involucrum; the fleshy bottom of these is the receptacle; and the choke, which is thrown away, is a collection of florets, separated from each other by numerous stiff hairs. The third section includes those Composite plants, which contain both sorts of florets,—ligulate ones in the ray, and tubular ones

in the disk; hence they are called Radiate flowers or *Corymbiferæ.* It sometimes happens that no ray is present; but the heads of tubular flowers cannot then be mistaken for those of the last section, since the florets of the latter are very wide-mouthed, and spread over the sides of the involucrum, the bracts of which are hard and spiny,—whilst in the former case, the tubular flowers are narrow at the mouth, and are not longer than the scales of the involucrum, which are soft and leafy. To this Radiate group belong the Sun-flowers, Chamomiles, Daisies, Marigolds, Groundsel, Wormwood, the beautiful tribe of Asters which add so much to the splendour of our gardens, and thousands of other species.

631. It must not be supposed that the clustering together of the florets in heads is so essential a character of this order, that every plant in which it exists is to be regarded as belonging to the Compositæ. The contrary is the fact; for although no plants of this order have other than composite flowers, there are several in other orders, in which the flowers grow in heads. The most important single character is the adhesion of the anthers into a tube; such perfect adhesion presenting itself nowhere else. Upon this is founded the Linnæan name of the group, which corresponds with the order Compositæ,—the class SYNGENESIA. In the whole of the subdivision *Cichoraceæ*, all the florets are complete, possessing both stamens and pistils; this is also the case in the greater number of the *Cinarocephalæ;* and the plants having this character were arranged by Linnæus into the order *Æqualis*, from the *equal* character of all the florets. This order also includes those of the *Corymbiferæ* which are destitute of *ray.* On the other hand, in the remainder of the Corymbiferæ, the florets of the disk only are perfect, possessing both stamens and pistils; and those of the ray seem to have the corolla developed at the expense of the stamens, which are absent: all the flowers, however, usually bear seed, those of the ray being fertilised by the pollen of those of the disk. This division was named by Linnæus *Superflua,* from the florets of the ray being as it were superfluous. In the common *Garden Marigold* perfect seeds are produced in the ray only, and this belongs to the Linnæan order,

Necessaria. Lastly, there are a few of the Cynarocephalæ in which the florets of the disk are perfect; whilst those around the margin are larger than the rest, so as in some instances to form a sort of ray (being still tubular, however,) and are entirely infertile. These are termed by Linnæus *Frustranea*, from their incomplete character.

632. It is chiefly among the Radiate group of this order, that those species exist, which are valued as garden plants; and cultivation has frequently a remarkable effect on them. The corolla of the florets situated towards the margin of the disk undergoes an increased development, at the expense of the true reproductive organs; and they are changed into ligulate florets, deficient in stamens, and exactly resembling those of the ray. This change is particularly evident in the *Dahlia*, which has repaid the attention it has received, by a greater improvement in the aspect of its flowers, than any other species, perhaps, has exhibited. In its natural condition, it possessed, like most of its group, but a single row of ligulate florets; and all the centre of the flower was occupied by the ordinary yellow disk. Under the influence of a rich soil, however, the number of rows of ligulate florets has gradually increased: and these have also undergone great changes in regard to their size, elegance of form, and beauty and variety of colour. When a Dahlia is spoken of as eight, ten, or twelve-bloomed, it is meant that it has eight, ten, or twelve rows of ligulate florets. In its highest state of excellence as a garden flower, the florets of the disk nearly or altogether disappear; and the smaller the *eye* (as it is termed) of the Dahlia, the better it is considered to be. Such flowers, however, are not fertile,—that is, they do not produce ripe seed; for the conversion of the complete florets into those bearing pistils only, occasions a great deficiency of pollen. It is curious to observe the change which will be produced in the flower of a Dahlia, if a root of the best kind be planted in a poor soil. There will be an effort, so to speak, to produce a large number of ligulate florets; but these will be stunted and often curiously twisted; so that the flower is even less handsome and regular than that of a much poorer kind. The Dahlia is a native of

Mexico; and in its wild state it is a bushy herbaceous plant, growing to the height of about seven or eight feet, with flowers by no means remarkable for their beauty. It was introduced into this country soon after the commencement of the present century.

633. The foregoing general account of the structure of this remarkable order, is all that the limits of the present Treatise permit to be given; a few remarks will now be added on its geographical distribution, its properties, and uses. The order attains its greatest development, in regard to the *size* of the species it contains, in the neighbourhood of the Equator; for whilst, in the temperate parts of the world, Compositæ are entirely herbaceous plants, those of Chili are bushes, and those of St. Helena are trees,—almost the only ones native to the island. But in regard to *number*, it would seem that they predominate rather in temperate regions, especially of the northern hemisphere, where they are considered as forming about one-sixth of the whole vegetation. In Britain, about 140 species of them may be reckoned, constituting about one-tenth of the whole number of native flowering-plants. In France they are estimated at about one-seventh, and in Germany at one-eighth; whilst in Lapland they are only one-fifteenth. In Sicily they are said to constitute more than half; and nearly the same proportion is found in some parts of North America. In the north of New Holland, on the other hand, the proportion is not more than one-sixteenth; and of a collection of plants formed upon the western coast of Africa, it did not exceed one-twenty-third. The Cichoraceæ have been ascertained to be more abundant in cold regions, and the Corymbiferæ in hotter ones.

634. In considering the properties of the order, it will be necessary to advert separately to each of its subdivisions. The *Cichoraceæ* as already stated, possess a milky juice, which is bitter and astringent, as well as narcotic. These properties are strongly manifested in the *Lactuca virosa* or strong-scented Lettuce; for the juice, when concentrated, has narcotic effects sufficiently powerful to enable it to be used for the purpose of procuring sleep, instead of opium; and the cells or vessels in

which it is contained, are so irritable at the time of flowering, that, if the surface be touched, the juice is forced out at the point. By proper cultivation, however, the injurious properties may be so far removed from several species of this group, such as the Lettuce, Endive, and Succory, that their fleshy stalks and leaves become wholesome articles of food. The roots, also, have often a considerable tendency to become fleshy, and may be generally eaten without danger. Those of the Succory are much used on the Continent, when roasted, as a substitute for Coffee; and their powder is very commonly mixed with it, being considered by many persons to improve its flavour. The roots of the Scorzonera and Tragopogon are known under the name of Salsafy, and are cultivated for the table in some places to a great extent; they are said to resemble those of Carrots and Parsnips in flavour. The roots of the Dandelion are used in Germany for the same purpose as those of the Succory; but in this country they are more employed for medicinal purposes, the extract prepared from them being considered by many as a useful tonic, promoting also the various secretions. In common with many other plants of this tribe, its leaves and stems are believed to be an excellent food for cows, promoting the secretion of milk to a great degree.

635. In the *Cinarocephalæ*, bitterness predominates; and the principle to which it is due is generally mixed with gum, which is sometimes yielded by the plants of this group in great abundance. This bitterness is not found, however, in the unexpanded leaves, or in the receptacles of the flower-buds; on which account they may in many cases be used as wholesome articles of food. This is the case with the Cardoon, the Artichoke, and several other species. The roots, also, of many species are edible. The flowers of several species yield a yellow dye, which is most powerful in the *Carthamus tinctorius;* this plant is supplied from the Levant, and is often used to adulterate Saffron, as well as to tinge silk and cotton goods.

636. In the *Corymbiferæ*, the bitterness common to all the Compositæ, is combined with a resinous principle of stimulating character, which exists, however, in very different proportions in the various species. Few supply articles of food; almost the only

species of which any part is eaten being a kind of Sun-flower, of which the root is known under the name of the Jerusalem Artichoke. The former part of the name is a corruption of the Italian *Girasole*, which means "turning towards the sun." The seeds of the common Sun-flower are a nutritious food for poultry, and they are made into cakes by the North American Indians; a large quantity of a fixed oil may be extracted from them (§. 371). The roots of the Dahlia are fleshy, but their taste is very disagreeable. Of the medicinal properties of this group, those of the common Chamomile, which is in repute as a tonic and stomachic, are a good illustration; but there are many species in which the bitter, the resinous, or the astringent properties are more predominant, and which have, therefore, their respectively peculiar uses.

637. Quitting this extensive and important order, we next proceed to one which appears very different, but which has, nevertheless several points of affinity with it; this is the order CAMPANULACEÆ, or *Hairbell* tribe, an extensive group, of which the species are scattered all over Europe, and in the cooler parts of Asia and America, dwelling in dells and dingles, by the banks of rivers, in shady groves, and on the sides of mountains. The British species are humble plants, bedecked with no other ornament than a few blue or purple nodding flowers; but in many foreign countries there are species of great brilliancy and richness of appearance, which are more striking from the barren nature of the situations in which they usually grow. The genus *Campanula* is so named from the *bell*-like form of its corolla; to which the latter part of its common English name — Hairbell — also refers. Of this genus alone there are eight species in Britain, any one of which may be selected for examination. The calyx

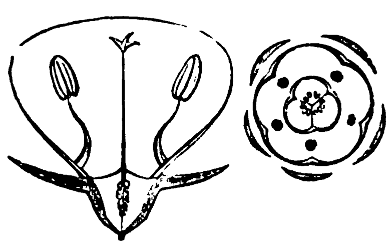

FIG. 170.—DIAGRAM OF THE FLOWER OF CAMPANULACEÆ.

in this order consists of five adherent sepals, which enclose the ovarium, and then spread away from the top of it. The corolla has very much the figure of a bell, save that it is marked by five divisions at its edge, which show it to be made up of five petals; and it is veined in a very beautiful manner. From its base, and consequently from the summit of the ovary, there spring five stamens, whose filaments are broad and leaf-like at the base, and curve inwards, so as to press the long narrow anthers against the style, around which they cluster in the unblown flower almost as do the adherent anthers of the Compositæ; as soon as the flower unfolds, however, the anthers shrivel and fall back. The style is a taper stiff column longer than the stamens. It is covered all over, to the very tips of the stigma, with stiff hairs, which Nature has provided to sweep the pollen out of the cells of the anthers, as the style passes through them in lengthening. If it were not for this simple but effectual contrivance, the pollen, which is set free by the bursting of the anthers as soon as the flower opens, would drop out of the nodding flowers, and be lost, before the stigma is expanded and ready to receive the fertilising influence. The hairs of the style catch the pollen, and keep it, until, by the agency of insects, by wind, or by other accidents, it is brushed down upon the inverted stigmas. Many Cichoraceæ are also furnished with these collecting hairs, which thus constitute another point of alliance between the two groups; this alliance seems the strongest in some species of Campanulaceæ which have the flowers crowded together in heads.

638. On examining the ovarium of the Hairbell, we find that it contains three cells surrounding a central axis; and that in each cell there is a large fleshy receptacle, to which a great number of minute ovules are attached. After these have been fertilised, and the rest of the flower has withered, the calyx still remains, inclosing the ovarium, and its sepals harden and enlarge; stout ribs appear in the ovarium; and the whole fruit, in ripening, becomes dry, brown, and hard. In most of the order, the capsule opens in the usual manner; but in the genus Campanula the mode is different. On looking at the top of the ovary between the sepals,—the point at which the separation of the

carpels generally commences,—that part is found to be even tougher than the sides; but Nature has provided another very simple means for the exit of the fruit, by the rending of the ovarium (when every part of it becomes stretched so tight in drying, that some part of it must necessarily give way) at its sides, between the ribs, where the skin is weakest. The rent takes place in such a manner, as to leave a large orifice to each cell, through which the seeds are readily scattered.

639. A large proportion of the plants of the Hairbell tribe are as harmless as they are beautiful; the roots of some species are eaten under the name of Rampion; the leaves of others are used in Salads; and the bells afford an abundant supply of honey to the Bee. The stem and roots abound in a milky juice (another character of alliance to the Cichoraceæ), which does not possess any deleterious properties. There is a subdivision of the group, however, of which a separate order has been formed by some Botanists under the name of *Lobeliaceæ*, the Lobelia tribe, which is distinguished for its extreme acridity. The species belonging to it are known by the irregular form of their corolla, which has some resemblance to the ligulate florets of the Compositæ; and also by the partial cohesion of their anthers; so that they approach the Compositæ still more decidedly than do the true Campanulaceæ. A character of much interest (which, however, can only be distinguished with the aid of the microscope) is, that in the true *Campanulaceæ* the pollen grains are round, whilst in the *Lobeliaceæ* they are oval. The plants of the latter group are most abundant in countries bordering on the tropics. Only two species are natives of England; but many more have been introduced into our gardens, where they are valued on account of the beauty of their flowers. One species, the *Lobelia inflata*, a native of North America, has been used in medicine as an emetic and expectorant, and has been accounted a most important remedy for Asthma; it is very uncertain, however, in its effects, and has produced fatal consequences when given in an overdose.

640. The last order of Calycifloral Exogens which will be here noticed, is that of Ericineæ, the *Heath* tribe, a group of extreme beauty, which is easily recognised by certain peculiari-

ties that distinguish it from all others. Of the common Heaths, the general aspect is known to every one; but there are many species far surpassing these in size, and differing so much in appearance, that they would not be associated with them by an unpractised Botanist. The true Heaths are most abundant at the Cape of Good Hope, where immense tracts are covered with them, and from which most of those exquisitely-beautiful species, which are cherished in our gardens and green-houses, are derived. Their corolla might be likened to that of Campanulaceæ; but the position of it is different; for both calyx and corolla are here beneath the ovarium, which is consequently *superior*. The calyx is usually small, and is cleft at the edge by four notches, which indicate that it is composed of that number of adherent sepals. The corolla is a tube, sometimes swelling out into a little globe, with four short teeth at the end, showing that this is composed of four petals, united up to their points. Arising from beneath the ovarium, and scarcely attached to the corolla, there are eight stamens, whose anthers are purple, and their two lobes separated towards their points like the prongs of a fork; the anther-lobes, instead of bursting in the usual manner, open by *pores* or minute apertures at their extremities,—a character which is peculiar to the Heath tribe, and marks every member of it. The ovary contains four cells, each including a great many ovules; it bears a single style, having a flat purple stigma, with four little projections upon it. This in time changes to a dry capsule that bursts by valves, scattering an immense multitude of seeds almost as minute as grains of sand; and these are frequently provided with little crests or fringes, which enable the wind to catch and disperse them, and are technically called wings.

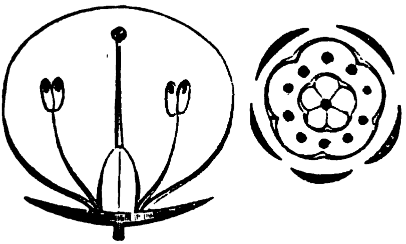

FIG. 171.—DIAGRAM OF FLOWER OF ERICEÆ.

641. The foregoing description applies especially to the true *Heaths*; there are many other species belonging to the order, which present several variations from it. For example, the calyx and corolla may be formed of five pieces, instead of four; the number of stamens may be equal to that of the petals, instead of double; and the number of cells in the ovary is variable. The essential characters of the order are the hypogynous stamens, and the opening of the anthers by pores. To this group belong the *Rhododendrons*, *Kalmias*, and *Azaleas*, which are now so abundant in our gardens; giving them cheerfulness, by their evergreen aspect, even in the depths of winter; and making them gay, with their beautiful blossoms, through the warmer parts of the year. The two former are natives of America; the latter comes from Asia Minor; but they are now all naturalised in this country, though liable to injury from the cold of winter, unless they are planted in sheltered situations. The Rhododendrons and Azaleas differ from the rest of the group in the irregularity of the corolla, which has unequal divisions and spreads open at the mouth; the stamens, too, are bent towards one side. The Kalmia is remarkable for the manner in which the stamens are held down by the corolla, until the pollen is ready to be shed; the filaments are curved outwards, away from the pistil; and the anthers are lodged as it were in little niches in the corolla, by which they are held, until the complete expansion of the flower, or any cause (such as the contact of insects) which gives the filaments a slight movement, sets them free, and they rise up with a spring, scattering the pollen on the stigma.

642. To what has already been stated of the geographical distribution of this order, it may be added that it is not abundant in Asia, and that it is almost unknown in Australia, where, however, its place is supplied by another, which differs from it in little but the structure of the anther. The general quality of the group is astringency; and several species have been used in medicine. Many species have succulent berries for fruit, which may be used as food; this is the case with the Arbutus, sometimes called Strawberry tree, from the flavour

and appearance of its berry, from which an agreeable wine is said to be prepared in Corsica. The Rhododendrons, Azaleas, and Kalmias, however, possess more active properties than the rest, and are decidedly poisonous to Man. The honey which is made from their flowers has proved extremely deleterious to those who have eaten of it; and it has been said that the flesh of Birds, that have fed on the buds of the Kalmia, becomes alike injurious.

643. The following tabular arrangement of the chief British orders that have been described in this sub-class, will assist the student in distinguishing them.

Sub-class II.—CALYCIFLORÆ.

Sepals of calyx adherent into a cup or tube. Calyx united to the disk. Petals and stamens apparently springing from the calyx.

A. Petals of corolla distinct, or nearly so.		
a, Carpels distinct, or but slightly adherent, each having its style and stigma.		
α, With stipules.		
Carpels numerous	*Rosaceæ*,	593
Carpels solitary	*Leguminosæ*,	586
β, Without stipules.		
Vegetation succulent	*Crassulaceæ*,	609
Vegetation not succulent . . .	*Saxifrageæ*,	615
b, Carpels completely united.		
α, Ovary superior.		
Stamens opposite the petals . .	*Rhamneæ*,	583
Stamens alternate with the petals . .	*Celastrineæ*,	582
β, Ovary inferior.		
Ovary 1-celled	*Grossulareæ*,	613
Ovary 2-celled	*Umbelliferæ*,	617
Ovary 4-celled	*Onagrariaceæ*,	599
B.* Petals cohering into a tube, to a greater or less extent.		
a, Ovary inferior.		

* This division, with the exception of Cucurbitaceæ, is placed by many Botanists who adopt De Candolle's system, in the next class. With the exception of the last order, Ericineæ, which is easily distinguished from all others, by the mode of opening of its anthers, they are at once known from the Monopetalous orders of the next sub-class, by their inferior ovarium.

a, Ovary 1-celled.		
Seeds numerous, placentæ parietal	*Cucurbitaceæ*,	606
Seeds single—Fruit dry . .	*Compositæ*,	629
Fruit succulent . . .	*Loranthææ*,	621
β, Ovary 2 or more-celled.		
Leaves opposite . . .	*Caprifoliaceæ*,	623
Leaves verticillate (in all the British species) . . .	*Rubiaceæ*,	624
Leaves alternate . . .	*Campanulaceæ*,	637
b, Ovary superior	*Ericineæ*,	640

Sub-class III.—COROLLIFLORÆ.

644. The members of this division are easily distinguished from the foregoing, by attention to the following particulars. The calyx and corolla are each formed in one piece,—that is, the sepals and petals are adherent at their edges; but they are quite distinct from each other, and from the ovarium, which is consequently always superior (save in a few exceptions). The stamens are adherent to the base of the corolla, and, as it were, inserted into it. The only one of the foregoing orders to which these characters apply, is the Heath tribe, which connects the preceding sub-class with this one, serving as an illustration of the general principle formerly mentioned,—that, in any Natural arrangment, such links must occur, the true place of which may be doubtful.

645. The first order in this sub-class, although of small importance, may yet be briefly noticed, because every one is familiar with some species of it, which will serve as an illustration of the general structure of the group. This is the order Primulaceæ, or *Primrose* tribe, the flowers of which are easily described. The Calyx is formed of one piece, cleft most commonly into five teeth, however, at the edges, indicating that it is composed of five adherent sepals; and a division of the same sort presents itself in the corolla, which has generally a rather long tube. On drawing away the latter, in the common Primrose, Cowslip, or Polyanthus, the stamens will come away with it; and on counting them, it will be found that they are equal in number to the divisions of the corolla, but are *opposite* to them, indicating

that there is a whorl deficient. This whorl is distinguishable in the genus *Samolus*, or Water Pimpernel (§. 465). The ovarium consists of but one cell, the placenta being central, and the partitions not being developed; it contains a large number of ovules. The style and stigma are single.

646. The great uniformity of these characters occasions the largest part of the order to be included in the Linnæan class and order PENTANDRIA *Monogynia;* and here we meet with several genera well known in Britain. Besides the Primrose, Cowslip, Oxlip, and Polyanthus,—which, it is said, may all grow from the same root, or be raised from the seeds of the same flower, thus showing them to be altered forms of the same species,—there is the *Anagallis* or Pimpernel, commonly termed the Poor-man's weather-glass, from its property of closing on the approach of a storm,—the *Lysimachia*, or Loose-strife, inhabiting moist places,—and the *Cyclamen*, or Sow-bread, so named because its tuberous roots, notwithstanding their very acrid character, are eagerly devoured by swine. This last plant is abundant in Sicily, and is the chief food of the wild-boars of the island. The group is extensively diffused over the globe, but is most abundant in northern and in mountainous countries; it is only cultivated for ornament, as it does not possess any properties which make it otherwise useful to man. It is interesting to remark that the genus Samolus, having the perianth adherent to the ovary (which is consequently *half-inferior*), is an aberrant form (§. 503) of the order, which leads us back into the preceding group. The difference is considered one of such importance, that, if it were presented by a greater number of Plants (of the Samolus only two species are known), they would be formed into a separate order.

647. The next order to be mentioned is one of more direct utility to man; this is the order OLEACEÆ or *Olive* tribe, of which some species inhabit England, although it is found most abundantly in the South of Europe. Instead of being humble and insignificant plants, the members of this order are always either trees or shrubs, and sometimes attain considerable size and beauty; such are the Ash and the Lilac. One of the

most common of the British species is the Privet, the fructification of which may be taken as an illustration of that of the order. The calyx is a four-toothed cup; and the corolla is formed of the same number of petals, adherent at their lower part into a tube, within which are two stamens. The existence of only two stamens within a regular monopetalous corolla, is a character which is nearly peculiar to this order, being shared with it only by the Jasmine tribe. The ovary contains two cells; and from the top of each hang down two ovules. The style is single, and is terminated by a two-lobed stigma. The ovary changes in ripening into a small round succulent fruit or berry, containing but one seed, the others not having been developed. These are the general characters of the Olive tribe; but there are some remarkable exceptions. The Ash, for example, is placed in this tribe, although it is destitute of corolla; for although this character would, if taken alone, cause a place to be assigned to it in the next sub-class, rather than in this, yet when it is remembered that the *natural* system is founded, not upon one or two characters only, but upon *general* conformity, it will be seen that the proper place of the Ash is in this order, since it agrees with the Olive in every important particular, except the absence of the corolla. A curious circumstance, which unequivocally proves their near relationship, is that the Ash and the Olive will graft very well together.

648. The most important species of this order is undoubtedly the Olive, the extensive cultivation of which in warm countries, on account of the oil yielded by its fruit, has been already noticed. The wood of the Olive is beautifully veined and takes a high polish; and having also an agreeable smell, it is much esteemed for ornamental work. The Ash is one of the most valuable of trees; both on account of the number of useful purposes to which its wood is applied; and because it flourishes in a greater variety of soil and situation, than any other tree producing equally good timber. It differs too, from most other trees in this,—that its value is increased, rather than diminished, by the rapidity of its growth. The wood of the Ash is chiefly distinguished by its elasticity; so that, although much less tough

than that of the Oak, and more easily split, it is not so readily broken by a cross strain. It is therefore of great use for agricultural and other implements; nothing being equal to it for poles, ladders, long handles, and other purposes, in which strength and elasticity are required in combination with lightness. The Ash seldom attains any great size as a forest tree; and it is not

FIG. 172.—THE ASH-TREE.

of consequence that it should, as the wood of moderately-old trees is the most serviceable. It is one of the most elegant, however, of forest-trees; being peculiarly distinguished by its lightness and gracefulness of aspect. Allied to the Ash, but possessing a corolla, is the Manna-ash, which (in common with other species) yields that peculiar exudation, consisting of sugar mixed up with a purgative principle, known in medicine under the name of Manna. This is brought to England chiefly from the South of Italy; and it is principally employed as an aperient for

children, who are attracted by its sweet taste. The leaves of the common Ash are said to have similar properties; and its bark, which is bitter, has been substituted for Cinchona bark in fevers. A remarkable fact respecting the Ash, which seems to show that the secretions of its leaves are injurious to other plants, is, that its *drip*,—that is, the rain that drops from its branches,—renders the ground unproductive around it.

649. Nearly allied to the Olive tribe is the small order JASMINEÆ or *Jessamine* tribe, a group of elegant and fragrant trailing shrubs, which differs but little from the preceding order. The divisions of the corolla are five or more instead of four; and the petals are imbricated, or fold over each other, before expanding, instead of having their edges in contact as in Oleaceæ. Moreover, the seeds rise up from the bottom of the ovarium, instead of hanging down from its summit. The Jasmines are most abundant, and attain their greatest fragrancy in tropical climates; the species which is cultivated in this country is not a native of Britain, but has been imported from the south of Europe.

650. The Order to be next adverted to is that of GENTIANEÆ, the *Gentian* tribe, which is distinguished by the vividness of the colours of its flowers, and the extreme neatness of the aspect of the foliage. This tribe may be known from all other Monopetalous Exogens, by the structure of its leaves, which are opposite each other on the stem, and have two, four, or more strong veins, parallel with the midrib. The Gentians have a regular corolla, formed, like the calyx, by the partial union of (most commonly) five divisions; it has somewhat of the *plaited* appearance, which is observed in the Convolvulaceæ. The stamens are equal in number to the segments of the corolla; the ovary is imperfectly two-celled, containing a large number of seeds; the style is single, but the stigma is two-lobed. The fruit ripens into a dry capsule with two valves. The tribe is not a very extensive one; and the principal part of it is met with in South America. There are some hardy species, which abound over the milder and more elevated districts of Southern Europe and Asia; covering the sides of hills with blossoms of such intense bril-

liancy, that the eye can scarcely rest upon them. Several genera of this order are common in Britain; the chief are the Gentian, and the Centaury. The whole order is characterised by the presence of a very bitter principle, which exists in the leaves, flowers, bark, and roots; this is much valued in medicine as a tonic.

651. Another well-known order, chiefly important on account of the valuable medicinal products which it yields, is that of CONVOLVULACEÆ, the *Convolvulus* or *Bindweed* tribe. The species with which we are familiar in this country, are for the most part trailing plants, depending for support upon others; but between the tropics, where the order especially abounds, we find it containing also standard shrubs and even trees. The calyx and corolla in this order each consist of five divisions; the sepals usually overlie each other so completely, however, that only the two outer ones can be distinguished. Very commonly the petals are so completely adherent, that they do not separate even at their extremities; this we notice in the common Bindweed of our hedges. This order is remarkable for the curious *plaiting* into which the corolla folds when it closes. In most species it opens and closes under the influence either of light or of darkness,—some opening only in the day, and others only at night; and there is one curious species, in which the flowers are so sensitive as to contract beneath the touch, like the leaves of the Sensitive plant. The stamens are five in number, and are opposite to the sepals of the calyx. The ovarium usually contains three or four cells, in each of which there are but one or two ovules; the style is single, but divides into two stigmas. The fruit is a capsule, opening by valves equal in number to the divisions of the ovarium. The form of the embryo is curious, and serves to distinguish this order from others that are nearly allied to it in the preceding characters; it is doubled up in a remarkable manner, as if there were not room within the seed for it to grow; and the cotyledons are small and shrivelled, being occasionally altogether absent. The greater number of species may also be distinguished from other monopetalous plants, by their milky juices; but this character is less apparent in the annual

species of temperate climates, which seem as if they had not time to elaborate them, than in those which increase from year to year, and form woody roots and stems.

652. It is among these last, that the peculiar characters of the order chiefly manifest themselves. They form an acrid resinous matter, possessing active purgative properties. This is especially abundant in the roots and rhizomas; and it is obtained from several species for medicinal purposes. The resinous extract known as *Scammony*, is the milky juice, obtained from a species that grows in the countries bordering on the Levant, and hardened by exposure to the air. The high price of this drug partly depends upon the heavy duty to which it is subjected; and it is one extremely liable to adulteration. The drug known as *Jalap* is the powdered root of an American species, from which also a resinous extract might be obtained; but the active principle exists so largely in the roots, that there is no necessity for thus concentrating it. When administered in proper doses, it is a safe as well as active medicine; it is also a very cheap one; and a very large quantity of it is accordingly consumed in this country,—between 2 and 300,000 lbs. being annually imported, chiefly from Vera Cruz. The common Bindweed of this country has similar properties in a less degree. There are some species of Convolvulus, however, which form a large fleshy root; and the resin contained in this exists in such small proportion to the starch, that it forms a harmless and nutritious article of food. These roots are known in tropical countries (in some of which they are much employed) under the name of *Sweet Potatoes*. The leaves and young shoots of these may also be eaten as pot-herbs.

653. This order includes a curious parasitic group, that of the various species of *Cuscuta* or Dodder, whose general habits have been already described (§. 344). The Dodder may be frequently seen on the stems of Heath, Furze, or Nettles, in the form of a cluster of stout reddish cords, which are so entwined together, that they might be almost taken for a knot of young snakes. The only vestiges of leaves consist of a few stunted scales; and it is curious that the cotyledons also are nearly

undiscoverable,—a character that shows the alliance of this group to the Convolvulus tribe, with which it is said also to agree, in the possession of purgative properties.

654. The next order we shall notice is also a large one, chiefly consisting, however, of humble plants; but these attract attention from their aromatic character, which occasions many of them to be cultivated by Man for various purposes; and also from their great abundance, especially in the northern temperate regions. The order now alluded to is that of LABIATÆ, or Labiate plants, so named from the peculiar form. of the corolla, which seems to have a pair of *lips;* we may designate it as the *Mint* or the *Dead-Nettle* tribe, from some of its best-known species. In all the preceding orders of this sub-class, both calyx and corolla have been *regular;* that is, their parts are equal, or nearly so. In the Labiatæ, however, this is not the case. The calyx is a little cup, with five teeth at its edge, which are sometimes equal; but in general it is divided by a deeper cleft, into two unequal lips, of which one has three teeth and the other two. The corolla is tubular at the base, but is divided above into two unequal lips, of which the upper one is narrow and concave, whilst the lower one is broad and convex; the upper consists of two adherent petals, and the lower one of three, of which the central one is usually the broadest. There can be no difficulty in recognising a *labiate* corolla from this description; but the plants belonging to the order may be even more readily distinguished by their stamens. These are four in number, lying within the tube of the corolla; and two are longer than the rest; so that their character is, in the Linnæan language, *Didynamous*, and the whole group corresponds with the first order of the Linnæan class DIDYNAMIA. In some instances, however, only two stamens are present. The anthers are peculiar in the great separation of the lobes, which touch each other only at their points; in the Sage, only a single lobe is developed (§. 432). The ovarium externally presents four divisions, from which it might be supposed to consist of four carpels; in reality, however, there are only two cells, each of which contains two ovules; and these four seeds, being large, give the form to the seed-

vessel which encloses them. The style is single, but cleft at the top, where it carries two stigmas. When the fruit ripens, the seed-vessel splits into four portions, each closely enveloping a seed, so as to form a sort of grain or nut like that of the Ranunculaceæ or Umbelliferæ; and the four are concealed in the bottom of the calyx, which does not fall off with the rest of the flowers. As the seeds, in consequence of the close adhesion to them of the walls of the carpel, do not seem to have a distinct envelope, they are frequently said (though erroneously) to be *naked;* and hence this group is placed in the Linnæan order *Gymnospermia*, with which it exactly corresponds. The Labiatæ principally inhabit dry situations in temperate climates; they constitute about one-twenty-fifth of the Flowering Plants of France and Germany; and diminish in their proportional number, as we pass towards warmer or colder climes. None of them are poisonous or even injurious; but their strongly aromatic character prevents them from being used as staple articles of food, though many of them, such as the Mints, Sage, Thyme, Rosemary, Balm, &c. are employed to give flavour to various dishes, or are valued for their medicinal properties. The aromatic principle is an essential oil, which is found in numerous receptacles in the leaves and stalks, and which contains a large quantity of camphor.

655. Nearly allied to the Labiatæ,—but distinguished from them by having a regular corolla, five fertile stamens, and a round instead of a square stem,—is the order Boragineæ, or *Borage* tribe; which includes a considerable number of herbs and shrubs, chiefly inhabiting the temperate latitudes of the northern hemisphere. Among the British species are several well-known plants of great beauty, such as the Forget-me-not (*Myosotis palustris*), Viper's Bugloss (*Echium vulgare*), and others. The common Borage is found pretty abundantly among rubbish and waste ground in Britain; it has an odour somewhat resembling cucumber, and communicates a peculiar coolness and flavour to any beverage in which it is steeped. In common with several other species of this order, it contains a small quantity of nitre, together with a large amount of mucilage; and it

is not unfrequently used as a domestic remedy. The common Comfrey (*Symphytum officinale*), growing on the banks of rivers and in watery places, also abounds in mucilage; and its young stems and leaves, when boiled, are sometimes employed as articles

FIG. 173.—BORAGINEÆ.

of food. In several species of this order, the roots contain a reddish-brown colouring matter, which may be extracted for the use of the dyers; the one chiefly cultivated for this purpose, however, is the *Anchusa tinctoria*, or Alkanet, the produce of which is largely employed in this country (§. 394).

656. The next order is also an extensive one, and it is of much greater direct importance to Man; supplying him with one of his staple articles of food, and with some of his most valuable medicines, as well as with other products in most extensive use; and notwithstanding this, it is one of the most poisonous tribes in the whole vegetable kingdom. This is the order SOLANEÆ, or *Nightshade* tribe, of which the common Deadly Nightshade will serve as a characteristic example. We here return to flowers whose structure is regular or nearly so. The calyx presents five equal teeth; the monopetalous corolla has five equal

divisions; there are five equal stamens; and the ovarium has two cells, in each of which is a number of ovules. In all these characters, there is nothing to mark the distinction of this order from the Gentianeæ, in which the structure of the flower is almost exactly similar. In the Linnæan classification, however, they are distinguished by this,—that the style is altogether single in the Solaneæ, so that the genera belonging to it are placed in the order *Monogynia* of the class PENTANDRIA, whilst many of those of the order Gentianeæ, in which the style is cleft at the top, belong to the order *Digynia* of the same class. A more important and constant distinction, however, may be drawn from the arrangement of the leaves, which are *opposite* in the Gentian tribe, and *alternate* in the Nightshade tribe. It is well, on account of the

FIG. 174.—BRANCH OF ATROPA BELLADONNA, OR DEADLY NIGHTSHADE, with buds, flowers, and fruit.

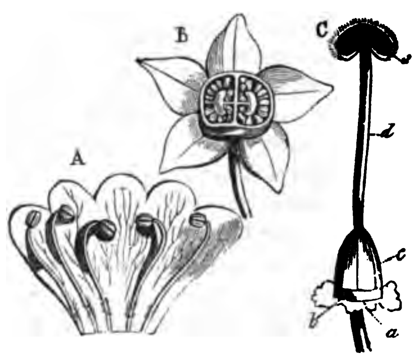

FIG. 175.—PARTS OF FLOWER OF THE SAME. A, corolla cut open, showing the stamens inserted on it. B, calyx, with ovarium cut across. C, pistil, with *a*, origin of calyx; *b*, origin of corolla; *c*, ovarium; *d*, style; and *e*, stigma.

poisonous properties of this tribe, to remember its distinguishing characters; and the following definition comprehends all that is necessary to distinguish this order from every other;—the flower is monopetalous and regular, the ovary superior with two cells; and the leaves alternate. The fruit consists of a capsule, which is very commonly swollen into a fleshy berry.

657. The native British plants contained in this order are the Bitter-sweet, whose red and tempting berries are a dangerous decoy to children, the Deadly Nightshade, Henbane, and Thorn-Apple. They are all distinguished by their narcotic properties, which render them serviceable in medicine when skilfully administered; but they have also a considerable degree of acridity, and often operate as violent irritants, when taken in an overdose or accidentally eaten. The order is widely spread over the globe, however; and some species of it are found in almost all countries except the polar regions. A large proportion are natives of tropical countries; and among these are several which are much employed by Man. The first to be mentioned, because the one in most general use, is the *Nicotiana*, the leaves of several species of which constitute Tobacco; this was used in Persia, in which country it grows, long before the discovery of America; but it is from that continent, and from the West Indian islands, that Europe now derives its chief supply. Two species only are in sufficient repute to make their cultivation desirable; and these must be very extensively grown, to supply the enormous demand that now exists for what was once considered a noxious weed. The practice of smoking tobacco was introduced into England by Sir Walter Raleigh, and the settlers who returned from Virginia, about the year 1586. The use of tobacco, like that of coffee, encountered much opposition. Laws were made against its importation, and severe penalties were ordered against the employment of it. Book after book was written to deter the public from its use; but, as in the case of other forbidden gratifications, the more attempts were made to prevent it, the greater was the use made of it. Even King James I. of England wrote a book against it, bearing the name of the "Counterblaste." In this, the habit of smoking is execrated as barbarous, being

derived from savages, and as in itself filthy; and the Royal Author not only condemned it as injurious to the health, but as absolutely poisonous. He gives the following ridiculous account of the appearances found in the bodies of inveterate smokers, as sober truth. "Surely smoke becomes a kitchen farre better than a dining chamber; and yet it makes a kitchen oftentimes in the inward parts of men, soyling and infecting them with an unctuous and oyly kind of soote, as hath been found in some great tobacco-takers, that after death were opened." He concludes with styling it "a custom loathsome to the eye, hateful to the nose, harmfull to the braine, dangerous to the lungs, and in the black stinking fume thereof, nearest resembling the horrible Stygian smoke of the pit that is bottomless." Notwithstanding such opposition, smoking, together with the use of snuff, has spread not only through civilized but among savage nations; and there is now probably no single product of the Vegetable kingdom which is so extensively employed.

658. That excessive smoking is injurious, like excessive indulgence of any other kind, there can be no doubt; that the more moderate practice of it injures the health of many persons, who would be very unwilling to give it up, is equally certain; but, in regard to the deleterious effects of the use of it, there is less to be said, than against the habitual employment of fermented liquors; and the discontinuance of the practice might be rather urged on the ground of cleanliness and economy, than upon such arguments. We quite agree with King James that "smoke becomes a kitchen;" and in regard to snuff-taking we are of the opinion of the barrister, who is said to have thus replied to a friend who offered him a pinch,—"Sir, if the Almighty had intended my nostrils for a dust-hole, he would not have turned them upside-down." We would seriously urge, upon our younger readers especially, the desirableness of not being drawn by example or ridicule, into a custom which has nothing really to recommend it, and which will often prevent them, by the expense and time it involves, from doing what they might for the improvement of their minds. Some idea of the amount of money expended upon this indulgence may be formed from the fact, that

about 25 million pounds are annually imported through the Custom-house for use in this country, of which the duty alone is about three millions and a half sterling; and as the duty is extremely high in proportion to its value (being 3*s*. per pound for all kinds, whilst the cost of the inferior sorts is but about 2½*d*., and of the best 6*d*., before paying it), smuggling is carried on to a greater extent than in almost any other article. It has been reckoned that one-fourth of the tobacco consumed in Great Britain, and three-fourths of that used in Ireland, is smuggled.

659. In striking contrast with the Tobacco-plant we have now to speak of another species of this order, the *Potatoe*, which might be thought to belie what has been said of the general properties of the group; but this apparent exception to the general rule has been already explained (§. 479). It is well known that the leaves, stems, and fruit, contain the narcotic principle, though in a less degree than those of many other species; and the juice which may be pressed from the uncooked potatoe itself is also unwholesome. Although the cultivated varieties of this plant are now so numerous, it is difficult to discover it with certainty in the wild state. It was first brought into Europe by the Spaniards, from the neighbourhood of Quito, in the early part of the 16th century; but it was not introduced into England until 1586, when it was brought by Sir Walter Raleigh from Virginia. It is said that he distributed a number of tubers in Ireland, where they were planted and throve exceedingly well; and that they were subsequently introduced into England from the Sister island. It is a remarkable fact in the history of this plant, that the colony of Virginia was some years afterwards saved from famine, by a large supply conveyed across the Atlantic from the very country to which they had so short a time before been sent. The Potatoe was not brought into general cultivation in this country, until the beginning of the eighteenth century; and it was near the close of it, before much attention was paid to the varieties of this plant, or before it was planted over a large extent of ground. It has this great advantage over most other vegetables which are standard articles of food;—that it can not only be cultivated in places where no

others can be profitably grown, but that it can be cultivated there at a small expense, and is less likely to be affected by unfavourable states of the weather, than are most other crops.

660. The last order of this group which will be here noticed, is that of SCROPHULARINEÆ, which may be explained as the *Foxglove* or *Snapdragon* tribe,—these being two of the species best known, and at the same time most characteristic of it. This order is remarkable, like the Labiatæ, for the irregularity in the form of its flowers, which is even carried (in many species) much further than it ever is in that group; but it is strikingly different from it in properties; for instead of being harmless and agreeable to the taste, many of the plants belonging to it are, like the Solaneæ, virulent poisons, having strong acrid and narcotic properties, and all are suspicious. Instead of being, however, like a great part of the Solaneæ, of a dark and lurid aspect, which might almost lead us to suspect their injurious character, the plants of the Foxglove tribe are for the most part handsome, often possessing very brilliantly-coloured flowers. This order could not be readily distinguished from the Labiatæ by anything in the structure of its calyx, corolla, or stamens, which last are (as in the Labiatæ) *didynamous;* but they are at once known by the structure of the seed-vessel, which does not present externally a division into four lobes, but only into two; each of the two cells encloses a large number of ovules, instead of containing only two; and in ripening, the seed-vessel forms a distinct capsule with two valves. By this last character alone, this group is separated from the Labiatæ in the Linnæan arrangement, being placed in the second order, *Angiospermia;* the name of which refers to the enclosure of the seeds in a capsule, contrasted with their supposed nakedness in the preceding one. This Linnæan order also includes the OROBANCHEÆ, or *Broom-rape* tribe, which is nearly allied to the Scrophularineæ, differing from it chiefly in the absence of leaves, and in its parasitic habits, which resemble those of the Dodder,—except that the former attach themselves to the *roots* of other plants, whereas the Dodder derives its nourishment from their *stems*.

661. The common *Foxglove* (Digitalis purpurea) is one of the

most handsome of the native British species of Scrophularineæ. Its corolla somewhat resembles the finger of a glove (whence its name is derived), and is of a crimson hue, its throat or entrance being spotted with rich purple; its border is divided obliquely into five very short segments, of which the two upper are the smaller. In the *Snapdragon*, the lower lip projects inwards in such a manner as to press against the upper, so that the entrance to the tube is quite closed; on pressing the flower sideways, however, the two lips separate, as if the mouth were opening. In the *Calceolaria*, or slipper-shaped flower, of which an immense number of varieties are now in cultivation in this country (§. 454), the lower lip is blown out (as it were) into the likeness of a clumsy slipper. In the *Scrophularia* (Figwort), on the other hand, the corolla is globular, with a very large upper and small under lip. It is curious to observe the tendency to a return to the regular form, which some of these plants occasionally exhibit. Thus, a monstrous form of the Snapdragon is not uncommon, in which the flower is circular, every petal having the same form, and each having the spur or downward prolongation, which is usually possessed by one alone; and five stamens of equal length being developed. An exception to the general character of the order, is presented by the common Speedwell, in which there are only two stamens; and also by many foreign species. It has recently been discovered that *Euphrasia* (Eyebright) and several other genera of this family are parasitic during the early part of their lives; obtaining their nutriment, like the Orobancheæ, from the *roots* of other plants, especially Grasses, on which their suckers are implanted. When they have attained a certain degree of development, however, they are able to live independently of such assistance, and the parasitic habit no longer continues.

662. The plants of this order are found abundantly in all parts of the world, from the coldest regions in which the vegetation of Flowering-plants takes place, to the hottest place within the tropics. One species is found in Melville Island, which seems too cold a situation for the Labiatæ; and several ornament the sterile shores of Terra del Fuego. They are mostly acrid

and bitter; and the leaves and roots of many species act as purgatives, and even emetics. These qualities are united in the Foxglove (which approaches in many of its characters to the Solaneæ), with a remarkable power of depressing the nervous system, and of diminishing the action of the heart; and, when cautiously administered, this is a medicine of great value.

663. The following table will enable the student to distinguish such of the orders of this sub-class, as he is likely to meet with among British Plants. Here, as elsewhere, it is to be remarked, that such tabular arrangements, being founded upon such *single* characters only as are easily recognized, do not at all represent the real affinities or relationships between the orders.

SUB-CLASS III.—COROLLIFLORÆ.

Monopetalous Exogens, having a superior ovary, and the stamens inserted on the corolla.

A. Flowers regular, stamens of equal length.		
a, Ovary 4-lobed externally . .	*Boragineæ,*	655
b, Ovary undivided.		
α, Carpels 4 or 5.		
Stamens opposite petals, . .	*Primulaceæ,*	645
Stamens alternating with petals, .	*Convolvulaceæ,*	651
β, Carpels only 2.		
Stamens 2	*Oleaceæ,*	647
Stamens 4 or more.		
Calyx imbricated . . .	*Convolvulaceæ**	
Calyx in a perfect whorl.		
Leaves opposite . . .	*Gentianeæ,*	650
Leaves alternate . .	*Solaneæ,*	656
B. Flowers irregular, stamens usually tetradynamous.		
a, Ovary 4-lobed externally . .	*Labiatæ,*	654
b, Ovary undivided.		
α, Stems leafy, not parasitic, capsule two-celled	*Scrophularineæ,*	660
β, Stems leafless, habits parasitic, capsule one-celled	*Orobancheæ,*	660

* This order is repeated here, because several of its species, as the Dodders, have less than four carpels developed in the ovary.

Sub-Class IV.—MONOCHLAMYDEÆ.

664. In this sub-class, the perianth never consists of more than a single whorl, which may be considered in the light of a calyx or of a corolla. In many instances there is no vestige of either one or the other, and the fructification is reduced to its simplest possible condition. It is interesting to remark that, although this group does not contain nearly so many species distinguished for their peculiar properties, as do the former ones, yet it includes a large proportion of those, whose stems furnish us with valuable timber,—for example, the Oak, Elm, and Fir tribes; so that it would seem, as if the suppression of some of the organs of fructification, by which the race is multiplied, were favourable to the development of the individual structure. The first two orders to be noticed are of no great importance in themselves; but, as they contain several British species, it is desirable not to pass them by.

665. Of the order Chenopodeæ, or *Goosefoot* tribe, the common *Goosefoot*, so named from the peculiar form of its leaves, may be considered as the type. It has a perianth composed of five adherent portions, at the base of which, and opposite to the segments, are inserted five stamens. The ovarium is superior and one-celled, and crowned with two stigmas; it contains but a single ovule, which is attached to the base of the cavity. The plants of this order inhabit waste places in all parts of the world, abounding mostly in the northern parts of Europe and Asia; they are mostly considered rank weeds; but some of them have been rendered by cultivation very serviceable to Man. Some foreign species are used medicinally, in the countries where they grow. The most important products of this order, however, are not of a medicinal, but of a nutritious character. Of several species, such as Spinage, the leaves and stems are used as potherbs; of others, such as Beet, the root becomes very fleshy under cultivation, and affords a large quantity of wholesome aliment. One species of Beet is cultivated in England

under the name of *mangel wurzel*, or root of scarcity, to furnish winter food for cattle; it is often a very profitable crop, the roots growing to the weight of 20, 30, or even 60 lbs.; and it does not exhaust the soil. Another species or variety of Beet is extensively cultivated in France, on account of the sugar which it yields; this product is not so good as that made from the cane, nor can it be raised so cheaply; nevertheless the nation is obliged to employ it, on account of the heavy duty which is placed upon the sugar of the West Indies, Brazil, &c. Another plant, which was at one time of much importance, is the *Salsola soda*, which, when grown near the sea-shore, contains a large quantity of the alkali Soda; and this was obtained from it by burning. Soda is now more abundantly procured, however, by other processes. Another British genus, the *Salicornia* or Glass-wort, was of similar utility; this is remarkable for having but a single stamen. The genus *Atriplex*, or Orache, deserves mention on account of its being *polygamous*, that is, bearing complete, as well as incomplete flowers on the same plant. The complete and stamineous flowers have a five-parted calyx; whilst the calyx of the pistilline flowers is formed of two valves only.

666. The next order to be mentioned is that of POLYGONEÆ, or the *Buck-wheat* tribe, which, like the last, contains many of the most common weeds that overrun waste places in every latitude, together with several important plants. The characters of this order are easily recognised. The perianth is composed of from three to six pieces, adherent at the base, and folded over each other,—sometimes to such a degree, as to give the appearance of a double whorl. The stamens are usually few in number, and are inserted in the bottom of the perianth. The ovarium is superior, with a single erect ovule in its cavity; and has more than one style or stigma. In these respects, the Polygoneæ do not present any marked difference from the Chenopodeæ; but they may be distinguished by this important character,—that, whilst the latter are destitute of stipules, the former have them very large, and cohering round the stem, so as to inclose the leaf-buds, before they expand, in the manner of a boot; this is well seen in the common garden Rhubarb. The seed usually

contains a considerable quantity of mealy albumen, which is increased by cultivation to such a degree, as to make it in some species worth raising, especially as these plants will usually grow on the poorest soils. The juices of these plants, however, are astringent and sometimes purgative, occasionally also possessing acidity. But in general these properties are diffused in no large amount through their substance; so as not to be easily available. The chief medicinal product afforded by this order, is Rhubarb, which is the root or rhizoma of one or more species of *Rheum*, and is best obtained from warm countries, though it has been produced in Britain. The garden Rhubarb of this country corresponds with the common Sorrel and Dock, which also belong to this order, in the acidity of its leaves and leaf-stalks, on account of which it is cultivated. The *Polygonum bistorta*, or Bistort, so named on account of the twice-twisted form of its roots, is one of the most powerful of vegetable astringents; and the roots abound in starchy matter, which, when the tan has been separated, may be used as food. The *Polygonum fagopyrum*, or Buck-wheat, should more properly be called Beech-wheat; since it derives both its scientific and its common name from the resemblance between its seeds and beech-mast. In China and many parts of the East, it has long been cultivated as a bread-corn, and it was introduced into Europe by the Crusaders; it is not grown to nearly the same extent in this country as on the Continent.

667. The next order, LAURINEÆ, or *Laurel* tribe, is almost entirely confined to tropical climates; and is chiefly interesting on account of the number of valuable products which it yields. The Common Bay is the most northern species; and this does not naturally grow in countries more temperate than those of the south of Europe. The order is easily known from those allied to it, by the mode of bursting of the anthers, which open by valves in the same manner as those of the Berberry (Fig. 80, §. 433). The perianth consists of four to six portions, arranged in an imbricated manner; at its base are attached the stamens, which are usually twice the number of its sequents. The ovarium is one-celled, containing one or two pendulous ovules; and it is sur-

mounted by a single style. This order contains, with many shrubby species, some which rank as large trees; one genus, however, differs from the rest in being leafless and parasitic; and it is remarkable that this is the only plant of the order which is a native of Africa; Professor Lindley, however, separates it from the Laurineæ, and makes of it a distinct order. The Bay laurel was formerly in repute as a medicine; but it seems to have been yet more esteemed among the ancients, since wreaths formed of it were awarded as victorious crowns, to those who had distinguished themselves by their courage in war, or by their superiority in learning. It is curious that the present university degree of *Bachelor* (of Medicine, Arts, &c.) should take its origin in this circumstance; the term Bachelor, is merely a corruption of the word Bacca-laureate, which means laurel-berried; the latter part of the word being also the distinction of the Poet, who is appointed to make verses, on stated occasions, in honour of the sovereigns of Britain. The Laurineæ are all aromatic plants, containing in their leaves, bark, &c., a powerful essential oil, which gives them a strong and pleasant odour, and a warm and pleasant taste. The most valuable products of this order are Cinnamon and Camphor. The former is the bark of the younger twigs of several species of Laurel, which grow best in the islands of the Asiatic Archipelago. Cassia bark is inferior to Cinnamon in strength of flavour, but is often passed off for it. Sassafras is another aromatic product of this order; it is brought from South America. Camphor may be obtained from nearly every species of the tribe, in greater or less proportion; but it is now found to be more abundantly yielded by trees of other kinds. The Alligator-pear of the West Indies (the first name of which is a corruption of the original name Avocado) is the fruit of a species of Laurel; it is much esteemed for its rich and agreeable flavour, and seems to be relished not only by Man, but by many kinds of animals.

668. Several of the Laurineæ are diœcious; and this is constantly the case with the *Nutmeg* tribe, which is nearly allied to them; in these, neither the stamineous nor the pistilline flowers contain a trace of the deficient organs. The nutmeg is the

single seed contained within the ovarium, which, in ripening, forms a fleshy fruit (not unlike the Apricot in appearance) that bursts into two halves, displaying the seed in its centre. The nutmeg is partly enveloped in a covering to which there is nothing analogous in most tribes of plants; this is called the *arillus;* and it is known as *mace.* The mace lies between the fleshy fruit and the contained seed; it does not form a complete covering, but has many large apertures, through which the dark seed appears. It is, when fresh, of a bright scarlet colour; but this changes in drying to a dull yellowish brown.* The Nutmeg was originally grown only in a small group of islands in the Eastern Archipelago, termed the Banda or Spice islands, of which the Dutch early obtained possession. That nation desired to secure to themselves the trade in this valuable spice; and they endeavoured so to regulate the quantity produced, that the price of it should be always kept up to a high standard. Sometimes they cut down trees; and in other instances, when the crop was too abundant, they even destroyed immense quantities of the spice. They more than once, however, suffered dearly for their avarice; the nutmeg trees of Banda having been nearly destroyed by the hurricanes and earthquakes, which spared other islands. The nutmeg has now been for some time cultivated by the English in Sumatra, and also in the West Indies. Although the quantity produced in the last-named islands has hitherto been very small, there can be little doubt that, if the trees received greater attention, it might be much increased; but the attention of the planters is unfortunately so much fixed upon a few objects,—such as Sugar, Coffee, Cocoa, and Cotton, which yield an immediate return, that they are apt to neglect what might ultimately be more profitable, especially if it do not succeed on a first trial. The quantity of nutmegs imported into Britain in 1839 was about 280,000 lbs.; but of this not quite half was kept for use in this country. Several species of

* When it is desired to preserve the nutmeg and mace as a curiosity, the best way to prevent the loss of the beautiful colour of the latter, is to keep the fruit in a thick syrup, made from the best white sugar.

this order bear aromatic fruits; but they are all much inferior to the true nutmeg.

669. Passing over several less interesting tribes, we come to one of great extent and importance,—the EUPHORBIACEÆ, or *Spurge* tribe, which is an order containing a large number of plants, distinguished for their extreme acridity, and mostly inhabiting tropical countries. A small number are natives of this country; and a few more are cultivated in our gardens. It is fortunate, considering the injurious properties of this order, that it should be easily distinguished from all others. The stems, leaves, &c. have a milky juice; the stamens and pistils are not contained in the same flowers; and the fruit ordinarily splits into three divisions when ripe. The general structure of the flower cannot be readily understood, by examining the common Euphorbias of this country; since they have a peculiarity which is characteristic of their genus. If the apparent flower of one of the Spurges be examined, it will be found to consist of a sort of cup divided into ten parts at its edge, and having a cluster of stamens arising from its bottom; with a long stalk in the middle, curved downwards by the weight of the ovary that grows upon its summit. These stamens are peculiar, from the circumstance of their having a joint in what appears the filament of each; and also in their *successively* growing up above the mouth of the cup, discharging their pollen, and then shrivelling up. It was formerly supposed that the whole of this structure constitutes one flower; and as the young Botanist would be likely so to consider it, it is desirable to explain the reasons why it is not now so regarded. In the first place, no other genus of this order has stamens and pistils united in the same flower. Again, there is no other flower, in which the stamens have jointed filaments, or the same confused arrangement. Further, in many species, a sort of cup-like membrane springs from this joint, much resembling a little calyx. For these and other reasons, each supposed stamen is now regarded as a single stamineous flower, and the portion of its filament below the joint as its flower-stalk; the ovary in the centre is in like manner a pistilline flower; whilst the cup from which they spring

is an *involucrum* of bracts, something like that of the Compositæ (§. 629);—the whole being thus a kind of *head*, rather than a single flower. In general the floral leaves are green, so that the whole flower is almost destitute of colour; but sometimes they present most brilliant hues.

670. In other genera of the order, the structure does not depart so widely from the ordinary type. In some of them we even find a double perianth, each whorl being usually made up of five or six divisions. The stamens are extremely variable in number; and the ovarium consists of three carpels (sometimes only two) which separate from each other in ripening; each of these incloses one or two ovules. A very good illustration of this structure is found in the *Palma Christi*, or Castor-oil Plant, which is often cultivated in gardens, on account of the handsome appearance of its leaves and clusters of flowers. Many of this order are very succulent; and several of the tropical species present very much the appearance of the Cacteæ, being leafless, and having their swollen stems beset with spines. Nearly all of this tribe possess acrid properties in a greater or less degree; but these are most powerful in the roots of the larger species, which are not of annual growth. In Africa and Asia, the leafless thorny Euphorbias are often planted for fences; and they serve most effectually to keep out intruders, injuring those who attempt to pass, not only by their sharp spines, but by the acrid juices which they instil into the wounds made by these. One of the most violent in its action of all the species of this order, is the Manchineel tree of the West Indies; the juice of which, when applied to the skin, produces corroding ulcers. It has been said that it is dangerous even to remain under the shadow of the tree, but this is an exaggeration; it has been stated on good authority, however, that, if a person take refuge under one of these trees from a shower of rain, the droppings become charged with its exudations, and produce troublesome sores on any part of the skin which they may touch. The juice of this and of many other trees has been used to poison arrows.

671. Although the juices of the leaves and stem are usually so acrid, other parts of the plant may be applied to various uses,

either as articles of food, or as valuable medicines. Thus the root of the *Jatropha Manihot* contains a large quantity of starchy matter; and this is easily freed from the acrid juice, by pressure and by heat, so as to be rendered quite wholesome; and in this state it constitutes a most important article of food, under the name of Cassava, through a large proportion of the tropical countries inhabited by Man. The oil of the seeds of the Castor-Oil plant is one of the mildest purgatives known; but that of the seed-coats is very acrid and dangerous. The seeds of the *Croton tiglium*, and of the *Jatropha Curcas*, or Physic-nut of the West Indies, also furnish an acrid oil, which is used in medicine as an active purgative and emetic; that of the *Croton tiglium* alone, however, is ordinarily employed in this country as a medicine, that of the *Jatropha Curcas* being now imported and brought into use as a lamp-oil, for which it is well adapted. There are some species, of which the juices are not strongly acrid; but all are suspicious. Besides these products, there is one that is obtained in considerable amount from this order, the value of which is every day becoming greater, from the new and varied uses to which it is applied. This is *Caoutchouc* (§. 367—9); which, although partly obtained from a tribe to be presently mentioned, exists in considerable amount in the Euphorbiaceæ also. This order presents itself in the largest proportion in tropical America.

672. Another important group, also widely extended, and affording many products of importance to Man, is that of URTICEÆ, the *Nettle* tribe. It will doubtless surprise those, who have no previous botanical knowledge, to learn that the Fig, the Bread-fruit, and the Nettle, belong to the same group, along with the Hemp, Mulberry, and Hop. However much these differ among themselves, they agree in certain general characters, which distinguish them from all others. These characters may be most readily seen in such plants as the common *Pellitory*, that grows on wall-tops and in waste places; in which the flowers are not crowded together, as they will be shown to be in the Fig and Bread-fruit, and in which the stinging hairs of the Nettle and its allies are not present. Of the flowers of this plant, as in the whole

order, a part are stamineous and a part pistilline; there are here, besides, some others which are complete, though the pistil of these is not fully developed. The perianth is divided into four lobes; and *opposite* to the base of each arises a stamen. This last character is common to the order; but the number of segments of the perianth differs. The pistil consists of one ovary containing a single seed; it is surmounted by a single style, with a stigma composed of a bunch of filaments like a brush; in other species there are very commonly two styles. The fruit contains but a single seed, and is closely wrapped round by the perianth, which does not fall off.

FIG. 176.—BRANCH OF BREAD-FRUIT TREE, bearing *a*, *c*, clusters of pistilline flowers; *b*, clusters of stamineous flowers.

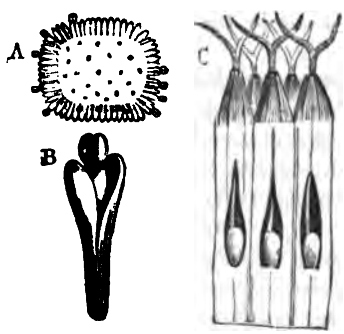

FIG. 177. — A, section of cluster of STAMINEOUS FLOWERS; B, single flower; C, three pistilline flowers, enlarged.

673. The greatest peculiarity in the organs of fructification, by which the Bread-fruit, Fig, &c., is distinguished, is not that the flowers are different in themselves, but that they are crowded together *upon* or

within a receptacle. This will be readily understood, so far as the Bread-fruit is concerned, from the accompanying figures. The stamineous and pistilline flowers grow in separate clusters, which are of different forms; that bearing the former is long, resembling a catkin; that of the latter is more globular, its bulk being principally composed of the fleshy receptacle on which the flowers are seated. The flowers are so much crowded together, that the perianth forms a cylindrical tube, composed of two pieces only. This, in the stamineous flowers, contains but a single stamen; and, in the pistilline flowers, it envelops a one-celled and one-seeded ovarium. During the ripening of the fruit, the receptacle enlarges, and becomes still more fleshy and succulent; and it is this which constitutes the edible portion. The structure of the Fig is extremely analogous to this; except that the flowers are borne on the inside of a hollow receptacle. This would not be understood upon examining the dry Fig only; but, if the unripe Fig be cut open, its structure is at once perceived. Its firm fleshy exterior is the receptable, which has grown up around the flowers, so as to direct them inwards towards each other, as if they were growing on the inside of a basin; this is not completely closed over at the top, however; for a little aperture is left there, which serves a very important purpose. The stamineous and pistilline flowers are both included in the same receptacle; but being so much crowded, the pollen of the former would not become applied to the stigmas of the latter, without some special contrivance. This is accomplished by the agency of insects, which enter the cavity through the hole at the top, and disperse the pollen by their movements. The seeds, which we meet with in the ripe Fig, are in reality little grains or nuts; being the hardened ovaries, closely enveloping the true seed, like those of the Ranunculaceæ.

674. We have now briefly to notice the chief products of this order, which is surpassed by very few in its importance to Man. The Bread-fruit is the chief support of the natives of a large proportion of the islands that are scattered through the Southern Ocean; it was introduced by the British Government into the West Indian Islands, where it grows very well; but is not much

relished by the negroes. The timber of this tree is light, and is used for building houses and boats; and the inner bark is beaten into a kind of cloth. Nearly allied to the Bread-fruit is the Mulberry, which is well known to be the source of all our silken fabrics, as upon its leaves alone can Silk-Worms be profitably reared. The Paper-Mulberry affords the material of paper to the Chinese and Japanese, the inner bark being beaten into a pulp, and then pressed into sheets; and its juice is so tenacious as to be useful as a glue. The Fig is an important article of food in many Eastern Countries; and it is highly nutritious as well as agreeable. A very large quantity is exported from these to various parts of Europe; as much as 1000 tons are annually brought to Great Britain alone, chiefly from Turkey and the Levant. Nearly allied to the Fig is the celebrated Banyan-tree of India (§. 152); and also the famous Upas, which has been reputed to be the most poisonous species of the whole Vegetable kingdom, causing the death of animals which even approached it, or of birds which fly over it. It is quite true that its juice acts as an extremely violent poison, when inserted into a wound; but the other effects attributed to the tree are not founded in fact. The Trumpet-wood of tropical climates affords the means of constructing canoes, furniture, &c.; and its fibrous parts are used as cordage; the same portion of the Hemp-plant of northern regions, supplies the material, not only of our rope and twine, but of many of our coarser woven fabrics, such as sail-cloth. In India, hemp is cultivated for the sake of the properties of its leaves, which have an intoxicating power, resembling that of opium. This valuable plant will grow in almost any climate and any soil; the country in which it is most cultivated, however, is Russia, whence a large quantity is annually imported into Britain. The amount of hemp of foreign growth, employed in the country in 1839, was nearly one million hundred-weight. The fibres are separated and prepared very much in the manner of those of Flax. It is curious that the Hemp-plant destroys almost every other plant that grows in its neighbourhood; so that it has been sometimes employed to clear from weeds a tract, which is afterwards to be used for some other kind of cultivation. The chief product of

this order, that now remains to be noticed, is Hops ; this consists of the little scales, which form a sort of cone like that of the Fir, having a small pistilline flower at the base of each ; these scales are to be regarded as bracts. This plant, although apparently truly wild in many parts of the country, is considered by some to be not a native of Britain, having been introduced from Flanders about three centuries ago ; but it is now very extensively cultivated, as much as 56,000 acres being employed for hop-gardens, of which nearly all are situated in the counties of Kent, Sussex, Worcester, and Hereford. The duty upon their growth is heavy ; and the crop is an extremely uncertain one ; so that the price is frequently high, and is liable to great fluctuations. In 1837, the excise duty on the Hops grown in England amounted to nearly £311,000, of which the county of Kent contributed one half. Besides their use in brewing, hops may be made serviceable, through their narcotic properties, in procuring sleep ; the use of a pillow stuffed with them has been much recommended in cases of habitual wakefulness.

675. The small order PIPERACEÆ, the *Pepper* tribe, claims notice on account of its utility to Man. Several hundred species are now known ; but they all so closely resemble each other, as to form no more than two genera. They are all tropical plants, abounding in the hottest regions ; and they all possess, in a greater or less degree, the pungent aromatic principle familiar to us. The Exogenous character of the group is by no means distinct ; and of it, with the addition of Menispermaceæ and a few other orders, Dr. Lindley has made a separate class, which he has termed *Homogens*. On the other hand, it has been placed by some Botanists among Endogens, more especially as in most species there is but a single cotyledon. The structure of the flowers is extremely simple. No vestige of the perianth remains, except a little scale, which is probably to be regarded as a bract; this protects the organs of fructification, which consist of a one-celled ovarium, surmounted by a stigma cleft into two or three divisions, and surrounded by two or three stamens partly adherent to it. These simple flowers are clus-

tered together in spikes; this is also the arrangement of the ripened grains, which consist of the ovarium inclosing the seed. These are known as *black* pepper; and it is when deprived of their husk, that they constitute *white* pepper; which is less pungent. The annual crop of each pepper-plant varies from half a pound to a pound; and the whole quantity collected every year for human consumption, is probably not far short of *fifty million* pounds. Of this a much larger proportion is consumed in tropical countries, the inhabitants of which are fonder of highly-seasoned dishes than in Europe; nevertheless, nearly ten million pounds are annually imported into Britain, of which only about one-fourth is consumed in the country. Pepper from other species forms a small proportion of the whole; *long* pepper, as it is termed, is the unripe cluster of flowers, which has nearly similar properties with the fruit. Cayenne pepper, as it is termed,—more properly Capsicum, is the seed-vessel of a plant of an entirely different natural order,—that of Solaneæ.

FIG. 178.—BRANCH OF BLACK PEPPER, with spikes of unopened flowers above, and of fruit below; *a*, portion of flower-stem, with three flowers; *b*, single fruit; *c*, the same cut open.

676. We now come to a very extensive group, which comprehends a large proportion of the forest trees of our own country and other temperate regions,—such as the Oak, Beech, Elm,

Plane, and Poplar, with the Birch, Willow, and many others. The name given to the order is AMENTACEÆ*, or *Catkin* tribe, on account of the arrangement of the flowers in most of the species, forming what is termed a catkin† ; but this arrangement

FIG. 179.—BIRCH.

is not universal. There is, indeed, considerable variety in this respect, as well as in the degree of completeness of the flowers, which sometimes contain both sets of organs, whilst in general the stamineous and pistilline flowers are distinct,—sometimes, even, being on separate trees. They all agree, however, in the simple structure of the flowers, as well as in other particulars.

* Professor Lindley divides the Amentaceæ into several orders.

† A *catkin* is a long flower-stalk on which the flowers are closely set ; and differs from a *spike* only in this,—that the whole falls off together, as is seen in the Poplar or Willow.

When the stamineous flowers are distinct, they are generally destitute of perianth, but the stamens spring from a sort of scaly disk; they are usually clustered together, either on a long stalk, forming a *catkin*, or on a sort of *head*. The pistilline flowers commonly possess a perianth in one whorl; they are sometimes solitary, and sometimes arranged on a catkin. What may be regarded as the most characteristic structure of the group, is seen in the *Poplar* and *Willow*. In these, the stamineous flowers are on one plant, and the pistilline on another; and both are arranged in catkins. Each of the former consists of a little bract, protecting one or many stamens; and each of the latter consists of a nearly similar bract, on which is set a one-celled ovarium containing many ovules. The fruit opens by two valves, which discharge a multitude of small seeds, covered with fine hair or wool, like the seeds of the Cotton plant. The Willow has no trace of a real calyx; but the Poplar has a sort of membranous cup, which may be considered as the rudiment of one.

FIG. 180.—CATKINS OF BIRCH.

677. A nearly similar structure is seen in the common *Hazel;* in which, however, the two kinds of flowers are arranged on the same tree; and the fruit more resembles that of the Oak. The stamineous flowers grow in catkins; but the pistilline flowers grow near these, clustered together within a scaly envelope, which looks like a little bud. At the time when the stamens are shedding their pollen, the clusters will be recognised by the little red threads protruding from their points, which are the stigmas.

The ovarium will be found carefully inclosed in the scales of which the bud consists, and protected by a quantity of soft hair. The ovarium contains two cells, with an ovule in each; but only one of these usually comes to perfection. The fertilisation of the seed is insured by the immense quantity of the pollen discharged from the numerous anthers, which settles upon everything around as a fine dust. Each pistil has a sort of imperfect calyx arising *above* the ovary, the remains of which may be traced at the point of the nut; but it is also inclosed in an involucrum of bracts, which increases as the fruit ripens, and almost envelops it, forming the *husk* of the nut. When the spring is mild, all the ovaria are fertilised, and the nuts ripen in clusters; but in cold springs it often happens that some of the pistilline flowers are destroyed, so that only single nuts are found in the place of the clusters. In the *Oak* and Beech the calyx is much more definite; and the involucrum is very peculiar in its structure, hardening into the well-known *cup* of the Acorn, Beech-mast, &c. The cells and ovules contained in the ovary are frequently numerous; but only one seed usually comes to perfection.

FIG. 181.—ACORN.

678. The importance of this order, on account of the valuable timber which it yields, is so well known, that it need not be here dwelt upon. It may be well to mention, however, that in propagating the various species, great care should be taken to select those whose wood is most durable. There is a remarkable difference in this respect, between two species of Oak, which are commonly grown in this country. Of one, which has the acorn-

stalks *long*, and the leaves *short*, the timber is close-grained, solid; and not liable to rot; whilst the other, which has the acorn-stalks *short*, and the leaves *long*, affords a wood of much looser texture, very apt to decay. The former is the Old English Oak, of which those ancient fabrics are constructed, that have resisted the ravages of time for many hundred years. The latter was probably introduced from the Continent about three hundred years since; and being more easily propagated, and of quicker growth than the other, it has been latterly substituted for it, especially in the New Forest, in the Northern counties, and in the neighbourhood of London. It is not unlikely that the late prevalence of dry-rot in our dock-yards is partly due to this cause.

679. Next to timber, the most important product of this order is *Cork*, which is a portion of the bark of a species of Oak common in the South of Europe. This peculiar substance, which consists entirely of cellular tissue, exists in many trees; but it is most abundantly found, and most quickly renewed, in this one. The cork is first taken off when the tree is about fifteen years old, and the next crop is removed ten years after; these two, however, are of little value, being thin and full of fissures. Afterwards the operation is repeated every eight or ten years; and a tree thus barked will live a hundred and fifty years. The importance of the secretions of *tannin* and *gallic acid*, which are afforded by the bark, acorn-cups, and gall-nuts of this order, has been formerly dwelt on (§. 365 and 399). Willow bark contains a bitter principle, which has been used in medicine as a substitute for that obtained from the Peruvian Bark. The *Myrica cerifera*, or Wax-plant of North America (§. 381), is a species of this order, allied to the Gale or Dutch Myrtle of this country.

680. The last order to be noticed in this group, differs so remarkably from all the rest, and in fact from all other Exogens, that some Botanists consider it in the light of a separate class. This is the order CONIFERÆ, all the members of which are distinguished by their fructification; this having the form of *cones*, of which those of the common Fir, Larch, &c., are examples.

These cones consist of a number of thick hard scales, which are adherent together until the organs of fructification are nearly mature, when they separate, so that the structure of the parts within can be distinguished. At the bottom of each of these scales are two ovules, which are not enclosed in anything like a seed-vessel. Hence these are the only true naked-seeded or *gymnospermous* Exogens; and the peculiarity is a very striking one. The dense scales were formerly considered as bracts; but

Fig. 182.—Inflorescence of Abies excelsa. *a.* Male Catkin. *b.* Anther, shedding its pollen. *c.* Female catkin. *d.* Scales of female catkin. *e.* Scale of ripe cone. *f.* Seeds.

little bracts may be often found at their base; and they are now regarded as the carpellary leaves, which have not folded in to enclose the ovules (§. 462). The stamineous flowers are arranged in catkins, much resembling those of the last order. The pollen grains fall directly upon the open points of the ovules; so that

the process of fertilisation is here as direct as it possibly can be. The seed is remarkable for having, in many species, a sort of verticil of cotyledons instead of two only; but these arise in the same manner as the two which we find in other Dicotyledonous plants, and may be regarded in the same light as leaves which present a corresponding sub-division (§. 235).

681. The Coniferæ certainly present the nearest approach to Cryptogamia, which we anywhere find in the class of Exogens. Their organs of fructification are reduced to the simplest form they can possess, whilst still maintaining the character which distinguishes the reproductive process in Flowering-plants. (§. 432). In the mode of growth of their stems, they are clearly Exogenous; differing from other trees of that class in little, except that they do not possess ducts, and that their woody fibre is of large diameter, and possesses glandular dots (§. 78). It is extremely interesting to be able to prove, by examination of such minute points of structure, the real nature of those vast deposites of Coal, which have long been a source of perplexity to those who interest themselves in inquiries into the history of our globe. Although in most instances the structure of Coal has been so much altered, by the combined agency of water, heat, and pressure, that it cannot be clearly distinguished, pieces may not unfrequently be found, in which it is very evident, when examined with the Microscope. It is then seen to correspond with Coniferous wood, both in the characters which have been just mentioned, and also in the presence of a number of little receptacles for secretion, in which a fluid is contained. This fluid may be separated by distillation at a temperature beneath that of boiling water; and it is found to be identical with Oil of Turpentine. It has been supposed, from the abundance of these remains of Pine forests, and from the absence, in the same deposites, of the remains of wood belonging to higher tribes of Plants, whilst the stems and leaves of Tree-ferns have been most perfectly preserved, that none of those higher tribes existed on the Earth's surface at that period. This inference, however, must not be relied on; for it has been found, by placing pieces of various kinds of wood, with Fern-leaves, and other Cryptogamic struc-

tures, to decay together in water, that, whilst all traces of Oak, Elm, Beech, and other hard woods were lost, the Coniferous woods could be distinguished, as could also the Palms; whilst the Ferns underwent little alteration. If such a process took place, as is probable, at a former period, the remains would be just what we find them; although many of the more perfect Exogens might have contributed to form them.

682. The various species of this order are distributed, as is well known, over the whole globe; but they principally abound in temperate latitudes, and flourish on the sides of lofty hills, where no other trees will grow. They are of great service in rendering ground fertile for other kind of vegetation, by the decay of their leaves and resinous excretions, at the same time that they are themselves a source of profit. Some species grow to an enormous height,—as much as 230 feet, with a perfectly straight stem. Every one is acquainted with the value of *deal* timber, on account of its combination of softness with elasticity and firmness, the size at which it may be readily obtained, the ease with which it may be worked. The greatest part of that which is used in this country, is brought either from Canada, or from Sweden, Norway, and Russia; the latter, which is called Baltic timber, is of the best quality, but is partly kept out by a heavier duty. The total quantity imported, is probably a great deal more than a *million loads* per annum,—by far the most bulky product which is brought to this country; the amount contributed to the revenue by the duty paid on it, is about a million and a half sterling annually.

683. The general characters of the foregoing orders are so distinct, that they will not be made more evident by being arranged in a table.

Class II.—ENDOGENS.

684. The number of orders belonging to this division of the Phanerogamia is much less than that of the Exogenous class; and many of these are of little importance to Man. There is one, however, which surpasses all others in the benefits, direct and indirect, which the human race derives from it. This is not, as might be imagined, an order consisting of lofty trees, whose stems and branches afford valuable timber, whose fruits serve as wholesome and nutritious food, and whose juices possess properties that render them valuable as medicines; but a tribe containing few save humble and apparently insignificant plants, undistinguished either by the beauty of their flowers, the fragrance of their odours, or the delicacy of their leaves; and having nothing in their general aspect, which could afford the slightest indication of their value. This order is that of the Grasses, which affords to Man his entire supply of the most nutritious of all vegetable substances, and on which are almost entirely supported the domestic animals which he rears for the food they yield, and for the other valuable products derived from them. We shall hereafter find, that this order ranks very low in the scale, considered in regard to its structure alone; and it is interesting to observe, in this as in so many other instances, the apparently insignificant means which the All-Wise Creator employs to effect objects of the greatest magnitude. It will be remembered that, in the class of Endogens, the parts of the flower are generally arranged in *threes*, not in *fours* or *fives*.

685. The first order to be noticed is a small one, containing the British aquatic plants named Frog-bit (*Hydrocharis*) and Water Soldier (*Stratiotes*), as well as many foreign species, especially in North America where it is most common; the first-named of these plants may be regarded as the type of the group, it is named after it Hydrocharideæ. The *Frog-bit*, (sometimes formerly called the lesser Water-lily, from its supposed resemblance to the plants of the order Nymphaceæ,) is common

in many ditches and ponds in this country; it has long stems which float on the water, sending down roots at intervals below, and erecting its leaves and flower-stems a little above the surface. The veins of the leaves run nearly parallel from the footstalk to the apex, and are united by little cross bars. The staminiferous and pistilliferous flowers are here distinct; the former are sometimes called *barren* flowers in botanical works, because they do not bear seeds, whilst the latter are spoken of as the *fertile* flowers. This is an incorrect application of terms, since the pistilliferous flowers can no more produce seed without the pollen of the staminiferous, than the latter can without the ovules of the former. In both kinds of flowers, we find a calyx of three sepals, surrounding a corolla with three petals. In the Frog-bit there are nine stamens, disposed in three rows, on the one flower; and within these, three imperfect styles; but in other species, the number of stamens is indefinite. The other flower is destitute of stamens, and has an inferior ovarium, consisting of six adherent carpels, with separate styles and stigmas, each carpel containing numerous ovules. In some the order, the partitions dividing the seed-vessel give way, so that the ovarium contains but a single cell.

686. The *Stratiotes*, which has been so named from its sword-shaped leaves and its fancied military appearance, is a very ornamental aquatic. It remains submerged during the greater part of the year, but raises itself to the surface on special stalks during the flowering season, by means of which contrivance the pollen may be scattered upon the stigmata. A still more curious means of effecting this object is met with, however, in another plant of the order, the *Vallisneria*. This plant, unlike the two already named, which prefer still waters, grows in rivers and rapid streams, of which the level is undergoing frequent and considerable variations. Now it is essential to the well-being of the plant, both in regard to the fertilisation of the seed and the ripening of the ovule, that the pistilline flowers, from the time of their expansion, should be kept on the surface of the water, and secured from frequent submersion. This is effected by a

very curious contrivance. They are themselves so constructed as to be lighter than water, and they are mounted on long cork-screw-like stalks, which are endowed with elasticity enough to enable them to extend when the surface of the water rises, just like a spiral spring when it is stretched out; whilst these contract again as the water sinks, so as still to keep the flower in close apposition with the plant. But the staminiferous flowers have no such provision; and as these grow from the part of the plant which is continually submerged, it would not seem evident how they are to come into proximity with the others, more especially as they commonly grow from separate roots. It has been observed, however, that, when the pollen is mature, and the anthers are ready to burst, the flowers producing it detach themselves; and, rising by their lightness to the surface of the water, they mingle with those already floating there, and discharge upon them their pollen, as soon as their petals are expanded under the influence of the sun. It has been further observed that, when the seeds are ripened, the spiral peduncle again contracts; and, carrying down the capsule, buries it in the mud.

687. The plants of this order are found in the ponds and streams of most countries; scarcely any of them, however, have been applied to any useful purpose; and none are characterised by any remarkable properties.

688. Another small order of aquatic Endogens is the one to which the *Sagittaria* (§. 227) belongs; it also includes a still more common plant, the *Alisma Plantago*, or Water Plantain, from which the name of the order, ALISMACEÆ, is derived. These are alike in most respects, in the structure of the parts of fructification; but the former has the pistilline and staminiferous flowers distinct (hence belonging to the Linnæan class

FIG. 183.—FLOWER OF ALISMA PLANTAGO, with the corolla removed, showing three sepals of calyx, and six stamens; *a*, undeveloped stamen.

Monœcia), whilst the latter has the two sets of organs united in each flower (and hence belongs to the Linnæan class Hexandria): the former also has more stamens than the latter. The Water Plantain has oblong, heart-shaped, pointed leaves, marked with about seven nearly parallel ribs or principal veins: and these are united by cross-bars, so that a kind of network is formed. The calyx consists of three distinct green sepals; and the corolla of three delicate pink or white petals. There are six stamens in this species of Alisma, *two* placed opposite each sepal; so that there must evidently be some portion of the flower deficient; since neither of these stamens corresponds with the centre of the sepal, as it should truly do, but each with one of its edges. Upon a more minute examination, a little glandular body may be found at the base of each sepal, and between each pair of stamens; this is obviously a rudimentary stamen, and thus the whole form an undeveloped whorl, perfectly opposite to the sepals. But neither of the six stamens stand opposite the petals, as one whorl should do if the flower were regular; so that we must imagine the rudiments of another row to exist in a state of still more complete want of development. In reality, then, the flower of Alisma, although containing six stamens, or two whorls only, must be regarded as constructed upon the plan of twelve stamens in four whorls, of which the outer can only be traced in a rudimentary state, the second being entirely deficient, and the two inner ones only being apparent. This scheme of suppression of parts may be expressed thus:—

1	Sep.			Sep.			Sep.		
2			Pet.			Pet.			Pet.
3	s			s			s		
4			o			o			o
5	st			st			st		
6		st			st			st	

The first line represents the position of the sepals; the second that of the petals alternating with them; the third that of the rudimentary stamens opposite the centre of the sepals; the fourth

that of the deficient stamens, which should be opposite to the petals; and the fifth and sixth, the rows actually present, the position of which does not properly correspond with that of the outer whorls of the flower.* Now this view of the matter, which may be considered forced and speculative, is very interesting when it is compared with the fact, that the tendency to the production of one or two additional whorls of stamens, which have been inferred to exist in this instance, is actually manifested in other species of Alisma, one of which has nine, and another twelve stamens. Had the six stamens been in the position represented in the third and fourth lines, there would have been no reason to suppose that any more existed in an undeveloped state, or that the plant was likely to be allied to any with 9 or 12 of these organs. The ovaries of the Alisma Plantago consist of about twenty-four (eight times three) carpels, which are quite distinct from each other, every one having its own style and stigma; they are arranged in a somewhat triangular manner, in three clusters. The number varies in other species, and may be regarded as indefinite. In most instances, there is but one ovule in each cell; and the fruit consists of a triangular head of dry one-seeded nuts, very much resembling that of the Ranunculaceæ. From the aquatic species of that order, indeed, in which the veining of the leaves departs from the regular Exogenous character, and the parts of the flower are arranged in threes, this group is not far distant; and this is one of the instances which show that even the most positively defined groups are liable to approach one another, through aberrant forms, in which the characteristic peculiarities of each are shaded off, until they almost blend together.

689. Some Botanists separate from this order the *Butomus* or Flowering-Rush, and its allies, on account of their many-seeded follicles, to the whole inner surface of which the seeds are attached; this plant receives its scientific name (which

* This view is given on the authority of Dr. Lindley; if the idea formerly suggested (§. 303), however, should prove well-founded, as to the parts of a verticil being often formed by a single leaf, a much simpler explanation of the double row of stamens may be adopted.

means cut-mouth) from the injury done by the sharp leaves to the mouths of the cattle that browse upon them. There is a marked difference in the properties of the two groups; for the British species of Butomus is one of the most acrid of our plants, its leaves being sometimes used as a purgative; whilst the Alismaceæ are much less so, their rhizoma or horizontal stem, which is fleshy in some species, being eaten as food by the Tartars and Chinese.

FIG. 184.—BUTOMUS.

690. The next two orders, both consisting of aquatic plants, may be considered as presenting a near approach to the aquatic Cryptogamia in general structure; and some species are very like Algæ in external aspect. They are clearly separated from them, however, by their organs of fructification; but these seem reduced to almost their simplest possible form. In the common *Duckweed*, for example, of which almost every pond will supply us with specimens, the whole plant consists of a little green scale, looking like a leaf, but really a compound of stem and leaf, from the under side of which, as it floats on the water, hangs down a single root-fibre. Few persons are aware that the Duckweed ever flowers; indeed there are some kinds which appear to reproduce themselves only by buds, as no organs of fructification can be detected; but, if properly sought for, the flowers of this little plant may usually be seen in the months of June or July. If the eyes be attentively fixed on a mass of it, on a still sunshiny day, a few minute straw-coloured specks may very probably be discovered here and there upon the edges of the plants; they have a sparkling appearance, which attracts observation. These are the anthers; and if the plants possessing them be more carefully examined, especially under a micro-

scope, the whole flower will come into view, having been previously hidden in a slit in the edge of the scale. The inflorescence consists of a transparent membranous bag, having a split on one side, through which the two stamens of the stamineous flower pass out; and within is also a pistilline flower with a single-celled ovary, having a single style and stigma. The sheath that incloses these is probably to be regarded as a large bract or spathe, like that which will be particularly described in the Arum tribe. Such are the means by which this little plant propagates itself, which it sometimes does with amazing rapidity. The Duckweed is so named, from its being a favourite article of food with water-fowl. It is the only genus of its kind known in Europe; and from its scientific name, *Lemna*, the group of which it may be considered as the type, is called LEMNACEÆ. In tropical countries, the surface of the water in ponds, tanks, &c., is often covered with a sort of gigantic Duckweed, termed *Pistia;* this has acrid properties, with which it is said to impregnate the water to such a degree, as to make it unwholesome. Neither *Lemna* nor *Pistia* have spiral vessels; so that in this respect they might be associated with Cryptogamia.

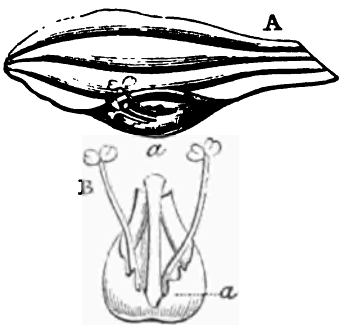

FIG. 185.—A, SCALE OF DUCKWEED, with flower *a* at its edge. B, THE FLOWER SEPARATED.

691. In the order NAIADEÆ, we have almost as near an approach towards flowerless plants; they are believed to be equally destitute of true spiral vessels; and they possess no distinct cuticle. In their general form and habits, many of them strikingly resemble Algæ; from which, however, they are at once distinguished when in flower. Of the British species, this resemblance is the strongest in the *Zostera marina*, or Grass-wrack, which is abundant on many parts of our coasts, and in

the creeks and salt-water lakes that pass inland. It is used, where it is common, for packing glass bottles and earthenware; and also in cottages for making beds and cushions. The Pond-weed (*Potamogeton*) of which a large number of species exist in Britain, is another plant of this order; its roots are fed on by swans, which devour them with avidity, whilst its seeds are a favourite article with ducks. One species is said to grow in the Swiss lakes to the length of from ten to twenty fathoms, forming as it were extensive subaquatic forests, in those vast natural reservoirs; in Siberia the roots of the species which most abounds there, are used as food by Man. The flowers of the plants of this order have a calyx and corolla, each consisting of two little scales, which very early fall off, and occasionally are altogether absent. Some species are monœcious, whilst others possess complete flowers. The stamens and carpels exist in a small definite number; but this varies in the different species. In *Potamogeton* there are in each flower four anthers, which, not being elevated upon filaments, are said to be sessile; and four ununited carpels, which become four small nuts. On the other hand, *Zostera* is monœcious. The plants of this order are most abundant in countries beyond the tropics, although they are also found near the equator. Potamogetons exist in almost every ditch and swamp, as far north as Iceland.

Order ORCHIDEÆ, *or Orchis Tribe.*

692. The plants associated with the common *Orchis* in this order, exhibit some of the most curiously-interesting modifications of structure, that any group in the vegetable world affords. Most of them are remarkable for the resemblance between their oddly-shaped flowers, and various objects with which they may be compared; thus two species of this country are known as the Bee-Orchis and the Fly-Orchis, from the similitude between their flowers and those insects; whilst others are known as the

Man-Orchis, the Lizard-Orchis, and the Lady's Slipper. In some foreign species there is an equally strong resemblance to large and splendid Butterflies and other Insects; one, again, reminds the observer of a grinning monkey; whilst another resembles an opera-dancer suspended by the head. The accompanying figure represents the Spider-Orchis, in which the likeness to the body of that animal is very striking. The Orchideæ of Europe grow on the ground, in meadows, marshes, or woods; and they are justly considered as among the most curious and beautiful plants of its Flora. But it is in tropical countries, in damp woods, or on the sides of hills, in a serene and equal climate, that they are seen in all their beauty. "Seated on the branches of living trees, or resting among the decayed bark of fallen trunks, or running over mossy rocks, or hanging above the head of the admiring traveller, suspended from the gigantic arm of some monarch of the forest, they develop flowers of the gayest colours, and the most varied forms, and often fill the woods at night with their mild and delicate fragrance. For a long time such plants were thought incapable of being made to submit to the care of the gardener; and Europeans remained almost ignorant of the most curious tribe in the whole vegetable kingdom. But it has been discovered of late years that, by care and perseverance, they may be brought to as much perfection in a hot-house as they acquire in their native woods; and they now form the pride of the best collections in England." It is chiefly in the almost impenetrable

FIG. 186.—SPIDER ORCHIS.

forests of South America that the *epiphytic* species (those that grow upon the surface of trees) are found; but in the hot damp

FIG. 187.—AERIDES ARACHNOIDES.

parts of the East Indies, other kinds are very abundant. Some epiphytic species are known as air-plants, from their power of vegetating when simply suspended in the air, without any soil or any direct supply of water, supported only by the moisture of the atmosphere; so that, when hung up by strings from the ceiling of a room, they will live for weeks and even months, and will go on blossoming luxuriantly. Hence they are some of the most favourite ornaments of the houses in China and Japan, of which countries they are natives.

693. As the structure of the flower is that which is most peculiar in this group, we shall proceed at once to a description of it. The short peduncle on which the flower seems to be borne, is in reality its ovarium, the position of which is *inferior*

in this order, whilst its form is slender. This contains but one cell, having three parietal placentæ, from each of which arise a great number of ovules. On examining the leafy parts of the flower, they are seen to be six in number, very irregularly disposed. The three external ones, which are considered as the sepals of the calyx, are seen in the adjoining figure (A) pointing upwards and to the sides; the two lateral ones in some species rise towards each other, and even meet and adhere, forming a sort of helmet-shaped arch, from beneath which the other parts of the flower project. The petals are also three, one of them being very much larger than the other two; the two small ones are seen in the figure to point upwards and outwards, alternating with the sepals; whilst the large one, pointing directly downwards, is that which has the greatest variety of form and colour in the different species, giving rise, by its curious metamorphoses, to the strange resemblances already alluded to. At the upper part of this transformed petal, which is termed the *labellum* or lip, is an opening that leads in many of the species to a long spur that projects below. The other leafy portions of the flower are, in general, very delicately-coloured on their interior side. So far, the structure of the flowers is not very difficult to understand, except in a few species in which the transformation is carried much farther.

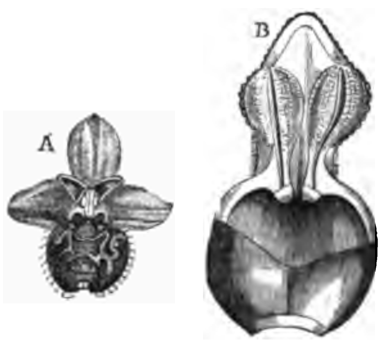

FIG. 188.—A, FLOWER OF SPIDER ORCHIS, much enlarged; B, ADHERENT ANTHER AND STIGMA, much enlarged.

694. The most remarkable peculiarity of the Orchideæ, however, consists in that modification of the special organs of fructification, to which Linnæus gave the name of *gynandrous*, and upon which he founded his twentieth class; and, as this is

universal throughout the group, and exists in no other, and thus distinguishes the Orchideæ from all other orders of the vegetable kingdom, the Linnæan class Gynandria exactly represents the order we are now considering. In the middle of the flower, just above the hole in the labellum which leads to the spur, half hidden by the petals, is a flat fleshy-looking body, represented on an enlarged scale, at B. The upper part of this is seen to be divided, by a channel down its middle, into two lobes, each of which is considerably swollen at one part of the side; and over this swollen portion there is a fissure, running from one end of it to the other, which will open if the lobe be pressed. If the contents of this swelling be examined, they will be found to consist of an olive-green mass, composed of minute granules adherent together, and tapering gradually into a long stalk, by which it is attached. On examining the nature of these granules with the microscope, it is clearly seen that they are in reality pollen-grains; and that thus the whole mass corresponds with the usual contents of an anther-lobe, in an adherent state. Hence it follows, that the whole of this curious structure is to be regarded as a metamorphosed stamen; the channel down its middle marking the division of the anther-lobes, and the fissures on the two sides being analogous to the suture or split, by which other anthers discharge their contents (§. 433). On each side of the base of the anther is a little roundish knob, which has something of a granular character, and which is to be regarded as a rudimentary stamen. At the foot of the anther (lower part of B, Fig. 188) is a pale fleshy cup, one side of which is curved over its cavity; this is called the *hood;* and at the bottom of it is the viscid stigmatic surface. Here, then, we have the essential parts of the apparatus of fructification; only one style and one stigma, however, being developed; and these being adherent to one another. This latter character runs through the whole of the Orchideous group; as to the former, however, there is some variation. Thus, in the *Cypripedium*, or Lady's Slipper, a British Orchideous plant, the two little prominences just mentioned are fully developed into stamens, whilst the central one, which is here developed, is rudi-

mentary; and in some other species, all three are occasionally present as complete stamens.

695. There is much difficulty in understanding how the usual influence of the pollen on the stigma can be effected in these plants; since the pollen is not capable of being scattered as a fine powder through the air, as in other plants; and if it were to fall out in a mass, it would hardly touch the stigma. Some have supposed that absolute contact of the pollen with the stigma is not necessary, and have thought that the fertilising influence could be communicated through the stalk of the pollen-mass. But this is now proved to be incorrect; as numerous experiments have shown that the contact is as necessary here as in other plants. It is difficult to perceive, however, in what manner it is naturally effected; and recourse has even been had to the supposition, that the agency of insects is necessary, in order to drag the pollen-masses from their case, and to diffuse their granules over the stigma.

696. On turning our attention to the general aspect of either of our commoner British orchises, we observe that it has a fleshy root usually consisting of two oval tubers, and of a number of succulent fibres; that its leaves, which have the simple-veined structure characteristic of Monocotyledons, spread upon the surface of the ground; and that a straight flower-stalk is shot up from the midst of these. The stem and roots are connected with but one of the tubers; the other arises as a sort of lateral bud from this one. When the stem has unfolded its flowers and ripened its fruit, it dies down to the ground, and is succeeded in the ensuing season by a stem developed from the second tuber, the first being exhausted. This, again, serves for the vegetation of one season only, and a new tuber is formed as a bud, from which the next year's stem will be developed. Hence the species possessing this kind of root, always have a pair of tubercles, one shrivelling and in process of exhaustion, the other swelling and in process of completion. Sometimes the bottom of the stem, instead of forming a new tuber upon its side, pushes out a slender subterranean root-like runner, which, after growing to some

length, is arrested and forms a tuber, from which the next stem is shot up; so that the plant may be said to change its place every year to a considerable distance. In many instances, amongst exotic species, the tuber is formed above the ground, constituting what is known as the *pseudo-bulb* of the Orchideæ; and its horizontal stem creeps along the surface as a rhizoma. In these cases, the structures are more permanent, the pseudo-bulbs acquiring a woody hardness, and continuing to send up stems; so that by their gradual multiplication, a large surface is often covered by a single plant.

697. It is remarkable that in a group so numerous as this,—consisting as it does of nearly two thousand known species, and of probably as many more which, being buried in the depths of unexplored tropical forests, have not yet been described,—and extending over almost the whole habitable globe, as far as the borders of the frozen zone,—there should be so few species possessed of properties, that make them in any way useful to Man. It often happens that the most powerful virtues, or the most deadly poisons, are hidden beneath a mean and insignificant exterior; whilst those productions of nature which charm the eye with their beauty, and delight the senses with their perfume, have the least relation with the wants of mankind. So it appears to be in this instance. The aromatic substance called *Vanilla*, which is sometimes used as an ingredient in chocolate, also to flavour sweet dishes, and to perfume snuff, is the succulent fruit of an Orchideous plant, which, in the West Indies, creeps over trees and walls like ivy. A nutritive substance termed *Salep*, somewhat resembling Arrow-root or Sago, is obtained from the tubers of a species which grows in Turkey and Persia, where it is highly esteemed. It used to be sold at the corners of the streets in London, and was a favourite drink with porters, coal-heavers, and other hard-working people, by whom it was considered very strengthening; and the comparative disuse into which it has fallen is perhaps to be regretted. It is said to contain a greater amount of nutriment in the same bulk, than any other vegetable substance; and for this reason it is much employed by

travellers, who have to carry their supplies with them into deserts and uninhabited countries. So high a nutritive power has been assigned to it, that it has been asserted that one ounce of Salep, boiled with an equal quantity of the stiff glue or animal jelly known as portable soup, in two quarts of water, will suffice for the daily nourishment of an able-bodied man. Some of the South American species contain a viscid substance, which, when separated by boiling, serves as a sort of glue, which is used by the Brazilians for sticking together their skins of leather. There is scarcely any other way in which this order is of any direct utility to Man.

698. Of the next order, SCITAMINEÆ, the *Ginger* tribe, there are no British representatives; but its structure will be very easily comprehended, as we now return to a nearly regular type of structure. They are all aromatic herbaceous plants, only coming to perfection between the tropics; and they are nearly all characterised by possessing a rhizoma, which creeps along the ground, and from the sides of which the leaf and flower-stalks are annually shot up. The flowers arise from expanded scaly bodies, which are clusters of bracts, one for the protection of each pair of buds. The ovarium, as in the Orchideæ, is inferior; and the calyx, which arises from its summit, is tubular, and is formed by three sepals adherent nearly to their points. Within this are two whorls of leafy organs, the outer of which is to be regarded as the true corolla, whilst the inner one consists of transformed stamens. In each whorl there are three segments;—those of the outer whorl, or petals, are partly adherent so as to form a tube, and are nearly equal—one being sometimes larger than the rest or differently shaped, so as to show some affinity with the Orchideæ. Of the inner whorl of transformed stamens, one is usually very much enlarged, like the labellum of Orchideæ, whilst the others are almost undeveloped. Within this whorl, there are three distinct stamens, of which, however, only one usually bears pollen; but this is quite distinct from the pistil. The ovarium is usually three-celled, though sometimes imperfectly so, the partitions not being complete, so as to ap-

proach that of the Orchideæ in character. The style is long and thread-like, dilated into an expanded stigma at the top. The fruit is generally a three-celled capsule.

FIG. 169.—GINGER PLANT.

699. These plants are generally objects of great beauty, either on account of the high degree of development of the coloured parts of the flower itself, or because of the rich and glowing hues of the bracts. They are, however, principally valued on account of the aromatic and stimulating properties, which the rhizoma of most species possesses. This is best known in the common Ginger, which is produced from a plant originally found in the south-east of Asia and the adjoining islands, but early transplanted to America and the West Indies, where it has been cultivated with great success, the Jamaica Ginger being esteemed much superior in quality to the East Indian. The dry Ginger of commerce is distinguished into white and black; but the difference of colour wholly depends upon the mode of preparation. For both these kinds, the rhizoma is allowed to remain, until the annual stalks are withered: the best and soundest roots being selected for white ginger, they are scraped clean and dried carefully in the sun; but the others are merely scalded and then dried. When a preserve is to be made of the root-stocks, they are

dug up whilst in sap, the stalks not being then more than five or six inches long. For this purpose, the young roots are scalded, then washed in cold water, and afterwards carefully peeled. They are then soaked for three or four days, during which the water is frequently changed; and being subsequently put into jars, a weak syrup is poured over them, which is afterwards exchanged for a stronger one, and so on for two or three times. The manner of cultivating ginger is extremely simple, requiring little care; it is propagated with as much ease, and nearly in the same manner, as potatoes are in Great Britain. Other species of this tribe are valued for their spicy qualities; such as the Turmeric Plant, formerly mentioned as yielding a beautiful yellow dye (§. 397), of which the powdered root-stock is one of the constant ingredients, with ginger, cardamoms, and other spices, in the celebrated curry-powders of the East Indies. The seeds also of some species, as the Cardamom, are aromatic, and are employed in medicine as cordials. The rhizoma of almost every plant in this order contains a large quantity of starch, which might be employed in the same manner as Arrow-root: but it is difficult to separate this in such a manner, as to free it from the pungent and resinous secretions with which it is intermixed.

700. The order MARANTACEÆ, or *Arrow-root* tribe, is so nearly allied to Scitamineæ, that some Botanists have associated them. They are, however, distinguished by a variation in the position of the fertile stamen in the flower,—a character which, as it is constant, is of great botanical importance, although apparently trifling; and there is also a difference in the structure of the seed. The properties also of the two orders are very distinct; for whilst, in the former, the secretions have universally a pungent stimulating character, they are destitute of any peculiarity in the present one; so that the large quantity of fecula contained in their rhizomas may be separated in a very pure state. The plant from which Arrow-root is ordinarily derived is a native of South America; but it is now much cultivated in the West Indies, and in some parts of Hindostan. It rises to the height of two or

three feet, has broad pointed leaves, and is crowned by a spike of small white flowers. Other species have more showy flowers; such is the *Canna*, sometimes cultivated in our hot-houses, the seeds of which are so hard as to have received the name of Indian Shot.

701. There are probably no Vegetable products that serve as articles of food to Man, which are produced in such large quantity, with so trifling an amount of care and attention, as those afforded by one or two species of the order MUSACEÆ or *Plantain* tribe. All the plants of this group are, like those of the two former, natives of tropical countries; the *Plantain* itself is not at present known except under cultivation, and being now almost universally diffused through the warmer regions of the globe, it is difficult to state what is its original habitation. The leaves of the whole are characterised by the peculiarity in the distribution of the veins, formerly mentioned (§. 231) as existing in the Plantain and Banana. In the structure of their flowers, we find in this order a still nearer approach to the regular type. These arise in clusters, protected by a large bract enfolding many buds, which is termed a *spathe*. The perianth consists of six pieces, all of which are frequently of brilliant colours; but as three are generally external to the others, they must be regarded as sepals of the calyx, whilst the inner ones constitute the corolla. They are all adherent at the bottom to the ovarium, which is consequently inferior; and they sometimes present a degree of irregularity. The stamens are six in number, but some are not unfrequently undeveloped; the anthers in many species are surmounted by a sort of crest resembling an expanded petal. The ovarium consists of three adherent carpels, which form distinct cells, each generally containing several seeds; the styles are united into a single column; but this separates at the top into three stigmas. The fruit is usually succulent.

702. The two most valuable plants of this order are the Banana and Plantain; the fruit is nearly the same in form and size, but differs in taste; that of the former being sweet, somewhat resembling a high-flavoured but over-ripe pear: whilst

that of the latter is nearly insipid. Their other differences, however, are trifling; and many Botanists consider that, as they are only known in cultivation, they are not unlikely to be varieties of the same species. They are most splendid plants, the stems formed by the cohesion of the leaf-stalks varying from ten to twenty or even thirty feet in height, and the leaves themselves being three, four, or even ten or twelve feet in length. The rapidity of their growth is most extraordinary. They are propagated by the separation of buds or suckers; eight or nine months after these have been planted, they begin to form their clusters; and the fruit may be collected in the tenth and eleventh months. When a stalk, on which the fruit has ripened, is cut, a sprout is put forth, which again bears fruit in three months. A cluster of Bananas, produced on a single plant, often contains from 160 to 180 fruits, and weighs from 70 to 80 lbs. A spot of little more than a thousand square feet will contain from thirty to forty Banana plants; and it is reckoned that from this number, in full growth, at least 4000 lbs. of fruit may be annually obtained. Humboldt has calculated that, from the same extent of ground, only about 33 lbs. of wheat or 99 lbs. of potatoes could be raised; so that the Banana appears to be 133 times more productive than the first, and 44 times more than the second. But this is not altogether true; since, weight for weight, the nutritive matter of the Banana cannot be compared with that of wheat or even of potatoes. Still, a much greater number of individuals may be supported upon the produce of a piece of ground planted with Bananas, compared with a piece of the same size in Europe growing wheat; Humboldt estimates the proportion as twenty-five to one.

703. The Banana flowers and bears fruit through the whole year, so that a constant supply is afforded by such a plantation, as that with which the natives of the countries where it flourishes surround their habitations. The labour of cultivating this is very slight; all that is necessary being to cut the stalks that are laden with ripe fruit, and to turn up the earth round the roots about twice a year. When families settle, the first step

towards their support is to establish a Banana walk; which, from the rapidity with which the plant grows, is soon accomplished; and this is afterwards extended as occasion may require. Humboldt remarks that a European traveller, newly arrived in the torrid zone, is struck with nothing so much as the extreme smallness of the spots under cultivation, round a cabin which contains a numerous family of Indians. Three dozen good-sized fruits are sufficient to support a man entirely for a week. They are not only eaten fresh, but are dried, like figs, in the sun; and a sort of meal may be extracted from them, by cutting them in slices, drying them in the sun, and then pounding them. It has been well remarked that "the facility with which the Banana can be cultivated, has doubtless contributed to arrest the progress of improvement in tropical regions. Necessity awakens industry, and industry calls forth the intellectual powers of the human race. When these are developed, man does not sit in a cabin, gathering the fruits of his little patch of Bananas, asking no greater luxuries, and proposing no higher ends of life, than to eat and to sleep. He subdues to his use all the treasures of the earth by his labour and his skill; and he carries his industry forward to its utmost limits, by the consideration that he has active duties to perform. The idleness of the poor Indian keeps him, where he has been for ages, little elevated above the inferior animal; the industry of the European, under his colder skies, and with a less fertile soil, has surrounded him with all the blessings of society,—its comforts, its affections, its virtues, and its intellectual riches."

704. The supply of food derived from the Plantain and Banana is not the only benefit afforded to Man by the order Musaceæ. The gigantic leaves of other species are used for thatching Indian cottages; they serve also for a natural cloth, from which the traveller may eat his food, and as a material for basket-making; and one species yields a most valuable flax, from which some of the finest muslins of India are manufactured. The stems of most of them, consisting as they do of the united petioles of the leaves, are remarkable for the very large quantity

of spiral vessels they contain, which may be pulled out in handfuls; these are collected in the West Indies, and used as tinder. The juice of the fruit of one species is employed as a dye.

705. The next order, IRIDACEÆ, or *Iris* tribe, is well known in this country by the wild species, commonly termed *Corn-flags*, which abound in moist and shady places, and by the more showy kinds introduced from abroad, which are now among our commonest garden plants. The order is characterised by the peculiar arrangement of the leaves, which are said to be *equitant*. If we pull one from its origin, we shall find that what appears to be a flat expanded leaf does in reality expose but half its surface, the leaf being folded together, so that its under side is entirely concealed. These folds are adherent together at their upper part; but at the lower they are commonly separated by a new leaf, which may be thus represented . It is from the resemblance between the position of the external leaf, and that of the legs of a man on horseback, that it is said to be *equitant* or riding. These leaves may probably be considered as in reality very large bracts, the true leaves being undeveloped; for the flower-stalks rise from between their folds, just as they do from within the sheathing bracts of Musaceæ, &c. In the Iris, the external whorl of the flower, as well as its interior, is brightly coloured; but this is not universal in the order. The three sepals are broad and spreading, and are often ornamented with a beautiful feathered crest; the three petals stand erect, and curve over the centre of the flower; and the stigmas are broad richly-coloured parts, resembling petals, and spreading away from the centre. At first sight it might be thought, that the Iris is almost destitute of stamens; but if the stigmas be lifted up, these will be found hidden beneath their broad lobes, they are three in number, and are remarkable for the peculiar position of the anthers, which have their faces (the side on which they open) turned towards the sepals, instead of towards the style. The carpels also are three in number, and adhere together so as to form a three-celled ovarium, the partitions

remaining distinct; but the styles coalesce into a single column. In the *Crocus*, however, of which the common garden species is so cheerful an indicator of departing winter, there are some important differences of structure. The stigmas do not expand, but are rolled up; still they are very large, and seem too heavy for the style; so that in the Saffron Crocus they hang down on the outside of the flower, like an orange-coloured tassel. The leaves, too, in the Crocus, are not equitant; so that this species departs widely from the general character of the group, and in fact connects it with the Amaryllis tribe. The growth of the leaves and flowers in the Iris takes place from an horizontal stem or rhizoma, which is not subterranean, but prostrate on the surface of the soil: and each successive yearly growth, instead of dying away as in other instances, continues in connexion with the foregoing; so that a mass of stem, bearing apparently distinct plants, is sometimes produced to a considerable extent, and is sometimes prolonged into branches by the development of lateral buds. In the Crocus, however, we find the leaves and flowers springing from a solid bulb, which must be regarded as a contracted stem; this neither lengthens upwards nor downwards to any considerable extent; but the buds formed from it separate (as in the Orchis), and the old bulb perishes.

706. The plants of this order are principally natives of the middle parts of North America and Europe, and of the Cape of Good Hope. They do not extend, to any great amount, between the tropics; nor into the colder parts of the temperate zone. The very numerous species belonging to it spring up at the Cape of Good Hope, upon the commencement of the rains; and soon cover the parched and bare-looking plains, with a robe of the deepest green, adorned with all shades of gay and sparkling colours. They are more remarkable for their beautiful fugitive flowers, than for their utility. The chief product they afford is Saffron, the uses of which have been already described (§. 397). The rhizoma generally contains nutritious matter combined with slightly aromatic secretions; this is used as food in some places where Irises abound; and that of the Iris Florentina, from its agreeable odour, is employed under the name of *Orris*

root, as an ingredient in tooth and hair powder. In a few species the rhizoma contains an acrid bitter principle, which has occasioned it to be employed with effect as an emetic and purgative.

707. Another very beautiful order of plants, for the most part inhabiting the same localities, is that of AMARYLLIDEÆ, the *Narcissus* tribe, of which the common Daffodil and Snowdrop of this country are examples. This is nearly allied to the last order, in the possession of a three-celled inferior ovarium, a single style, and a three-parted stigma; but the stamens are here six in number, and their faces are turned, in the usual manner, towards the style. This is a very important character, for it is constant throughout the order; whilst the opposite position is equally characteristic of the Irideæ, serving to distinguish those members of each, which are otherwise most nearly allied. The perianth consists of six portions, amongst which there is little difference in form or colour: but as they form two whorls, the outer one must be regarded in the light of a calyx. There is often, however, a departure from the regular form, in the partial development only of some of these. Thus in the Snowdrop the interior whorl is very small, and is almost contracted into the little fleshy bodies, which are sometimes called nectaries. In the Narcissus, again, besides the two whorls of the perianth, there is a sort of fleshy cup or nectary, which is shown to be formed of the rudiments of an additional whorl, by being sometimes converted into an outer row of stamens, and sometimes into an inner set of petals,—a metamorphosis, which, in an allied genus is constant. The plants of this order generally arise from a *scaly bulb*, which consists of a shortened expanded stem, surrounded by fleshy colourless leaves (§. 149), the true roots originating from its base; sometimes, however, the axis separates at once into roots, without this expansion. The leaves are usually sword-shaped, with veins running nearly parallel from one extremity to the other.

708. It is interesting to remark that, whilst the external characters of the last two orders are so nearly the same, the minute differences which have been mentioned,—the number of

the stamens and the positions of the anthers,—should indicate most important variations in their properties. For, whilst nearly all the Irideæ are harmless, and some are nutritious, the Narcissus tribe are characterised by their poisonous properties. These are principally apparent in the viscid juice of the bulbs of African species of Hæmanthus, into which the Hottentots are said to dip their arrows in order to render them venomous; but they have long been known in other kinds. The narcotic odour of the common Narcissus was known to the ancients; as was also the emetic principle contained in its bulbs, which is at the present time sometimes employed in medicine. Its juices appear to combine narcotic and acrid properties, which are so powerful, that two or three drachms of the extract will destroy life in the course of a few hours. Many of the species of the genus *Amaryllis*, which is especially abundant in South America, are distinguished for the fragrance of their flowers; this is much diminished, however, by the effects of cultivation, which sometimes causes the flower to become double. One species is cultivated for the sake of its roots, especially in Peru, where they are eaten as potatoes are in this country.

Order LILIACEÆ, *or Lily tribe.*

709. The species associated by De Candolle under this order may be advantageously separated, on account of their number, and their differences of structure, into three subordinate groups, the *Asphodel* tribe, the true *Lily* tribe, and the *Bromeliaceæ* or Pine-Apple tribe. The *Asphodel* tribe includes the Hyacinth, Onion, Squill, &c., and is remarkable for the extreme simplicity of the structure of all its parts, and for the strong similarity which exists in the flowers of the different species. They have all a perianth consisting of six pieces of similar form, size, and colour, arranged in two rows,—the outer one, therefore, being calyx, and the inner one corolla. Within the latter are six stamens; and in the centre is a *superior* three-celled ovarium, which changes to a fruit containing many seeds, covered with a black brittle skin. The majority of the plants so characterised

are quite harmless, and remarkable either for their use or their beauty. Their stems arise from scaly bulbs, from the bottom of which the roots are developed. These bulbs (and others similar to them) may be regarded as buds, in which the leaves are thick and fleshy, including a store of nutriment for the young plant, and the development of which may be delayed (as in seeds) for an indefinite time, without the loss of their vitality. This is a beautiful adaptation to the circumstances in which these plants are formed to grow; for they are naturally inhabitants of places which at certain seasons of the year are quite dried up, and where all vegetation would perish, if it were not for some such provision as we find in the bulb. In places like the hard dry karroos of the Cape of Good Hope, where rain falls only during three months in the year,—or the parched plains of Barbary, where the ground is rarely refreshed by showers except in the winter months,—and on the burning shores of tropical India, beyond the reach of the tide, and buried in sand, the temperature of which often rises to 180°,—bulbous-rooted plants are thus enabled to live, and to enliven such scenes with their periodical beauty.

710. Although, however, the bulbous structure, and herbaceous vegetation, are very common among the *Asphodel* tribe, they are not universal; for many plants have little or no trace of bulbs; and some species, especially between the tropics, attain considerable size and age as trees. The most gigantic of the order is the Dracæna Draco of the Canary Islands, from which the resinous colouring material named Dragon's Blood, is derived; one of these has been stated to be between 70 and 75 feet high, and 46½ feet in circumference at the base, and to have been a very ancient tree in the year 1496. The principal differences in the structure of the familiar plants of our own climate, are to be found in the varieties of degree, in which the parts of the calyx and corolla are united to each other, and in the formation of a stem covered with leaves,—the first rudiment of the arborescent stems and branches of the tropical species. In the *Onion*, for example, all the parts of the perianth are distinct; but in the wild blue Hyacinth, or *Blue-Bell* (as it is more commonly

termed), they cohere nearly to their points; and in another genus they are completely glued together. Again, in the *Asparagus*, the stem, when full grown, is repeatedly branched, and covered with little taper leaves, so as almost to resemble a Dracæna in miniature. Throughout this order, the leaves are long and narrow, like green straps, with simple parallel veins, sometimes much resembling those of Grasses.

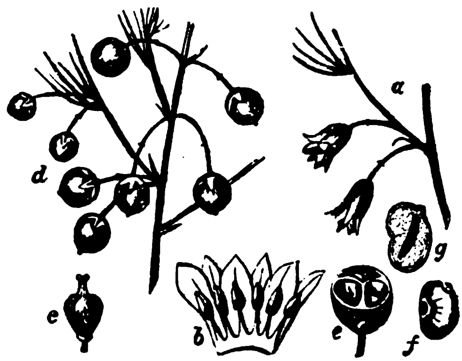

FIG. 190.—ASPARAGUS OFFICINALIS. *a*, flowers; *b*, corolla opened to show the stamens; *c*, pistil and ovary; *d*, fruit; *e*, horizontal section of the fruit; *f*, seed, magnified; *g*, vertical section of the same.

711. Many of the plants of this order are great favourites in gardens, on account of their showy flowers; and of the foreign species, several are easily naturalised in this country. Such are the *Asphodels* themselves, which are not natives of Britain, but which have long been ornaments of our gardens. The bulbs generally contain a large quantity of fecula, which is usually mixed, however, with a peculiar secretion, that imparts to it a strong and frequently unpleasant taste, together with powerful medicinal properties. In the Onion, Garlic, Shallot, and other plants belonging to the genus *Allium*, the taste is such as to render them valuable to give flavour to other articles of food, whilst the more active principle is only present in small quantities; and many of these, when the quantity of fecula is increased by cultivation (which does not increase the amount of peculiar secretions in the same degree) are themselves employed as articles of food; especially when their taste is rendered less strong and acrid by the heat employed in their preparation, or by the warmth of the climate in which they grow. Garlic and onions have been esteemed in Egypt from very early times;

and the account of the traveller Hasselquist shows that there is good reason for the superior value there set on them. "Whoever," he says, "has tasted onions in Egypt will allow that none better can be had in any part of the universe. Here they are sweet, in other countries they are nauseous and strong; here they are soft, whereas in the northern and other parts they are hard, and their coats are so compact that they are difficult of digestion. Hence they cannot in any place be eaten with less prejudice and more satisfaction than in Egypt." The onions of Spain and Portugal, and even those of the South of France, are for the same reason very superior to the common onion of our gardens, being of a much larger size, and more mild and succulent; yet the latter is looked upon, by the rustic inhabitant of many parts of Britain, as his chief vegetable dainty; and the garlic, which is too strong for most people in this country, is equally relished by the poorer classes on the Continent as an adjunct to their black bread, and even by the rich as an ingredient in their dishes.

712. The common Hyacinth deserves especial mention, on account of the interest taken in it for the sake of its beautiful flowers, and the numberless varieties of these which cultivation has induced, rather than for any particular service of which it is capable. The Dutch florists, who have particularly attended to this tribe, had at one time upwards of two thousand varieties of one species; and although the *mania* for speculating in Hyacinth and Tulip bulbs has now long since passed, these still form a branch of Dutch commerce by no means unimportant. The Squill bulb, preparations of which are much employed in medicine, as emetics, expectorants, &c., is acrid, bitter, and nauseous to the taste; it is a native of the South of Europe, growing freely on the sandy shores of Spain, Italy, and Greece; it sometimes attains the size of a man's head. The Asphodels also contain a bitter principle, which is removed, however, by boiling; one species, which covers immense tracts of land in Apulia, affords abundance of nutritious fodder for sheep; and pigs are said to be so fond of the bulbs, that they will unearth the roots to devour them.

713. One of the most interesting tribes belonging to this extensive group, is that of the *Aloe* and its near allies, most of which are highly ornamental plants, whilst some afford a very serviceable drug, and others supply products capable of being applied to many important uses. They are remarkable for the large size of the leaves, which are thick and fleshy, and which sometimes attain the length of eight feet or even more; each terminates in a hard sharp point, about half or three-quarters of an inch in length, and in appearance not unlike the claw of a beast of prey; so that a hedge or fence made of a series of these plants is quite impenetrable to cattle, and almost so (in consequence of the great toughness of the leaves) even to Man, unless well provided with cutting instruments. The proper juice of the Aloe is very bitter and stimulating; and the extract made from it is much used in medicine as a purgative. The species which yields it in the largest quantity, and in the most active form, is cultivated at the Cape of Good Hope, whence large quantities of it are imported into this country; the drug is also obtained from several species that grow in Barbadoes, but this is less pure than the other, and is principally used in this country by farriers, &c.

714. Nearly allied to the Aloe is the *Phormium tenax*, the plant which yields the (so-called) New Zealand Flax; the fibres of which are very much stronger than those of hemp, whilst they may also be prepared in such a manner as to become beautifully white and lustrous, like silk. Many attempts have been made to propagate this valuable plant, both in Britain and in Australia; as yet, however, these have not been attended with

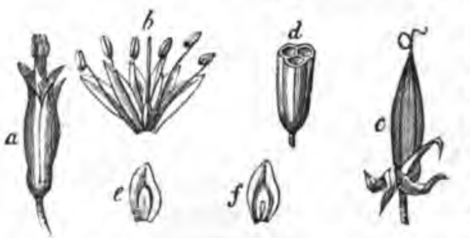

FIG. 191.—PHORMIUM TENAX. *a*, flower; *b*, the same opened to show the stamens; and pistils; *c*, fruit; *d*, horizontal section of the same; *e*, seed; *f*, the same in section.

any great success. Still it is imagined, that, if its cultivation were extended to a considerable amount in its native clime, the New Zealand Flax might be introduced into this country at a price far below that of Hemp and Flax, whilst superior to them in quality.

715. The points in which the plants of the true *Lily* tribe differ from Asphodels, are not striking or numerous. The leaves are similar, being narrow and strap-shaped, with simple parallel veins; and these, together with the flower-stalks, shoot up from underground bulbs. Moreover, if the flower of the Tulip or Lily be examined, it will be found to consist of six leafy portions, similar in colour, size, and form, and differing only in position, just as in the Onion tribe. Further, these envelop six stamens, within which is a three-celled ovarium, containing a number of ovules in each cell. The two groups, however, are more different in their general characters, than their agreement in these particulars would lead us to suppose. The Lily tribe are remarkable for their greater general development, and the far superior size of their flowers; this becomes apparent, when we compare Asphodels and Hyacinths, pretty as they are, with Tulips, Lilies, Crown Imperials, &c. The particular character by which they can be best distinguished, is derived from the nature of their seeds; which instead of having in the Liliaceæ, as in the Asphodeleæ, a hard black brittle coat, have a soft pale spongy integument. Moreover, they attain their greatest development in the warmer parts of the temperate zone, rather than in the equinoctial region. Their juices, too, are much less impregnated with peculiar secretions; so that the bulbs are more edible. Some of them are cultivated abroad, as the potato is here, especially in Siberia; in this country they are generally used for emollient poultices. The scent of the Lily is so powerful, that it distresses many persons to have the flowers near them, especially in a room; but that of a species cultivated under the name of the Tuberose is much more powerful, especially in the evening. This is one of the flowers that has been seen to emit electric sparks, which are supposed to be of electric origin. The Tulip, on the other hand, is a scentless though a very showy flower. It has been chiefly rendered famous by the commercial gambling

of the Dutch, a century or two ago. To such an excess were fictitious speculations carried, that the madness of the period was not unaptly termed Tulipomania. Single bulbs were bargained for, to be bought or sold, for upwards of £500 apiece.

716. The subdivision of *Bromeliaceæ*, or the Pine-Apple tribe, is separated by some Botanists to a considerable distance from the others, on account of the hard dry character of the leaves, and the firm herbaceous structure of the calyx, the sepals of which are not coloured as in the previous tribe. The most characteristic species is the Pine-Apple, which is believed to have been originally confined to the New World, and to have been propagated thence, by the early discoverers, to those parts of Asia and Africa in which it has been subsequently found apparently growing wild. It is not known to have been cultivated in England, until the end of the 17th century; but at the present time, the skill and attention of British gardeners have rendered the fruit grown in this country more prized for flavour and elegance, than that produced in its native climates. Great expense, however, is incurred for this purpose; so that a Pine, which might be bought for sixpence in a West Indian market, costs the English grower almost as many pounds. This is very different from ordinary fruits, consisting of a large number of ovaria with their perianths grown together and become succulent, somewhat as in the Bread-fruit (§. 673).

717. To this tribe would seem properly to belong the *Agave* or American Aloe, which, from its strong general resemblance, is commonly associated with the true Aloe; it is included, however, by Lindley amongst the Amaryllideæ. Its various species were originally natives of tropical regions, where alone they attain their proper size; but they have been introduced into the South of Europe, where they will grow wild in the open air. The leaves have very much the character of those of the Aloe; and from the midst of them is sent up after a long interval, a tall and elegant flowering stem, which attains a height of from 20 to 40 feet, growing very rapidly when once its development begins. The period before flowering in Mexico is from eight to eighteen years; and in the specimens grown in this country, the interval

is so much prolonged, as to be commonly reputed a hundred years. The fibres which may be obtained from the long straight veins of the leaves of the Agave, are very strong, and may be employed for various useful purposes. They are tougher, but less

FIG. 192.—AGAVE AMERICANA.

elastic, than those of hemp; and being very durable, they are of great utility to the inhabitants of the countries where these plants abound. When the hard point is forcibly separated from the leaf, especially after this has been soaked in water, it draws with it a bundle of these fibres; and these may be employed as coarse thread, whilst the point itself is used as a needle; whence this natural product has been called "Adam's needle and thread." The fibres are employed in Mexico to make a strong twine, of

which are composed the ropes that are commonly used there in the mines; and on the Western coast of that part of America, rigging for ships is made of them. The Mexicans cultivate it largely, however, for another purpose. When the Agave has arrived at maturity, a spirituous liquor is obtained by tapping the stem, which is a favourite beverage of the lower classes, under the name of Pulque. A good plant yields from eight to fifteen pints of pulque per day, during two or even three months; and the large quantity consumed may be judged of from the fact that, before the Revolution, a very small municipal duty exacted at the gates of the two large towns, Mexico and La Puebla, upon the pulque brought into them, amounted to about £170,000 sterling a year. Several species of Aloe are capable of affording very strong and valuable fibres; and among these is one known in the West Indies, under the name of the silk-grass-plant, the fibres of which are so extremely like those of white silk, that the importation of them into some countries is forbidden, in order to prevent imposition.

718. Nearly allied to the Lily tribe is one, of which the members are as distinguished for their poisonous properties, as for the beauty of their flowers. This is the COLCHICACEÆ or *Meadow Saffron* tribe, the flower of which, like the Lilies, has a double perianth, all whose parts are alike in form, size, and colour; it has also six stamens, and a superior three-celled ovarium. The *Colchicum* (Meadow Saffron) itself is very like a Crocus in its flower; but its superior ovarium prevents it from being confounded with the tribe to which that belongs. Other species approach very closely in general aspect to the Asphodeleæ; but they may be easily distinguished by three marks. In the first place, they have no bulbs, but a solid knob or swollen under-ground stem, like that of the Crocus; secondly, the face of the anthers is turned, as in the Irideæ, to the outer side of the flower; and thirdly, the styles of the several carpels remain distinct, so that there are three instead of one. The Meadow Saffron is remarkable for the singular form of its flower, and for the mode in which it is connected with the bulb; the portions of the perianth are united so as to form a tube, and this is

immensely prolonged (sometimes to the extent of 8 or 10 inches), shooting up directly from the tuber, without being supported by a flower-stalk. As the ovarium lies near the bottom of this tube, whilst the stamens are situated in the expanded part of the flower, the styles are necessarily very long; and the performance of their peculiar function under such circumstances is extremely curious. The Meadow Saffron of this country is termed *Colchicum autumnale*, from its peculiar season of flowering, which is in September or October. The flowers are large, and of pale purple; they spring up without leaves, forcing themselves through the soil, and expanding just above the surface. They then wither away; but the seed-vessel, being then scarcely elevated above the bulb, is protected beneath the ground during the winter. In spring, the leaves are put forth, and they carry up with them the seed-capsules, which then ripen. The bulb, however, is at this time exhausted; and a new one is formed at its base,

FIG. 193.—COLCHICUM AUTUMNALE. A, Bulb with flowers; B, bunch of leaves and capsules; C, ovarium and styles; D, seed-vessel cut across.

from which the flowers of the next season are developed. These bulbs contain (as in other instances) a large quantity of starch; and this, if freed from their peculiar secretions, is highly nutritious. But the juices are very acrid and powerfully irritating; so that the bulbs of most of the species, especially the Colchicum and Veratrum (commonly called White Hellebore), are of a very poisonous character. Their properties are such, however, as to render them very useful when properly administered as medicines; and these they possess in the greatest intensity about June or July; at which time, therefore, the bulbs should be gathered. The active principle exists also in the seed-coats, from which it may be extracted by spirit of wine. It is said that the bulbs of some species of Colchicaceæ are eaten, without injurious effects, in the South of Europe. The order is pretty widely distributed over the globe, but especially abounds in the northern hemisphere.

719. The order JUNCACEÆ, or *Rush* tribe, has apparently but little relation with the tribes last described; yet if its structure be closely examined, it will be found to be similar in all essential particulars to that of the Lilies, Asphodels, and Meadow Saffron. Many of the commonest Rushes are humble leafless plants, with stiff slender wiry stems, and little clusters of dingy flowers; others are still smaller in stature, but possess distinct leaves. These are usually long and narrow, resembling those of the Grasses. The structure of the flowers can scarcely be made out, except by the aid of a magnifying-glass and a strong light, on account of their minuteness and dull colour, and also through their being closely packed in clusters. When carefully examined, however, each flower will be found to possess a spreading perianth of six pieces, of which three external form the calyx, and three internal the corolla; on the outside of these are two or three bracts, so like them as scarcely to be distinguished from them, except by their position. From within the flower arise six (sometimes only three) stamens; and in the centre of the latter is the superior ovarium, which has three angles, indicating its formation from three carpels, and also three stigmas; but the style is single. In the true Rushes, the ovarium has three cells;

but in some other species it is one-celled, from the absence of the partitions; the placenta is central, and commonly bears three ovules. The seed-vessel often contains but one seed, the rest of the ovules being undeveloped; the seeds are enveloped in a pale soft skin. Now it will be observed that there is very little essential difference between the flowers of the true Rushes, and those of the Lilies and Asphodels; the number and arrangement of the sepals, petals, stamens, and carpels, being in all the same. The difference chiefly consists in the *degree* of development of the calyx and corolla, which is greatest in the Lilies, less in the Asphodels, and least of all in the Rushes; which last may be regarded as the lowest of the Endogenous tribes, whose flowers are constructed upon a regular plan.

720. The Juncaceæ are chiefly found in the colder parts of the world, and even in the coldest, two being natives of the ungenial climate of Melville Island. From the absence of higher orders of plants in such countries, Rushes form a large part of their whole vegetation; thus in arctic regions they are estimated at 1-25th, whilst in temperate latitudes they are but 1-90th, and in tropical countries 1-400th. The uses to which they are applied by Man are few. They are employed, as are also other plants belonging to the *Sedge* tribe (§. 733), for making chair-bottoms, baskets, mats, &c.; and before carpets came into general use, the floors even of palaces were strewed with them. It is on record that one of the charges of extravagance brought against Cardinal Wolsey was, that his room was strewed with fresh rushes as often as once a week. The cellular tissue filling the interior of the stems of Rushes, which has very much the appearance of pith, is in great request, in country places, to form the wicks of candles, hence called rush-lights. The Juncaceæ usually grow from a rhizoma, which is often itself branching, and which sends out long spreading roots. Hence they are employed, with other plants of a similar character, to strengthen embankments raised to keep out water from low lands, by binding together the soil of which they are composed; it is in Holland that they are of the greatest service for this purpose.

Order Palmaceæ, *or Palm Tribe.*

721. Palms were called by Linnæus the Princes of the Vegetable kingdom; whilst to Lilies he assigned the designation of Patricians or Nobles. The Palms exceed most other plants in size, and surpass them all in grandeur and majesty of aspect. They naturally, therefore, commanded the earliest attention of mankind; and the innumerable purposes to which their fruit,

Fig. 194.—Cocoa Nut Palm.

their leaves, and their stems have been applied, as food, clothing, and shelter, have worthily retained for them that regard which their beauty at first excited. They all bear a strong general resemblance to each other, and hence were early distin-

guished by a peculiar name. They are mostly remarkable for the size and strength of their stems, which usually shoot up to a great height from the ground, tapering gracefully from the base to the summit, and surmounted with a magnificent crown of gigantic leaves. These towering stems (which, when growing in sheltered situations, are often perfectly straight) sometimes attain the height of 200 feet or even more. Other species, however, have stems which trail along the ground; and these extend to the length of 500 feet; such is the common Cane, which differs from the Bamboos and other *Canes* properly so called (which belong to the Grass tribe) in having a solid instead of a hollow stem. Although the trunk usually sends out no branches, it occasionally subdivides into two, and these again separate, as in the Doum Palm of Egypt. The Palms are remarkable for the prodigious development of their organs of fructification. A single bunch of the staminiferous flowers of the Date contains about 12,000 blossoms; whilst another species has been estimated to bear above 200,000 in one cluster, and three such clusters on each individual.

722. Although the flowers are frequently complete,—each containing both stamens and pistils, — they are more frequently polygamous; that is, both complete and incomplete flowers are borne on the same individual. They are crowded together in large clusters, upon a stalk which is termed a *spadix*, having an enormous bract developed from its base, termed the *spathe*, which enwraps them all. The perianth consists of six pieces, in two

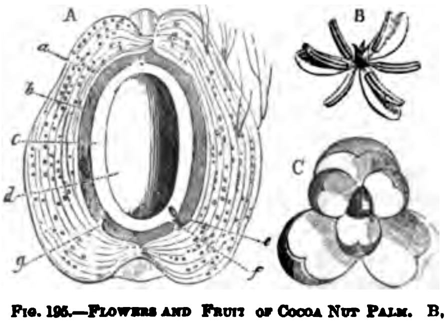

FIG. 195.—FLOWERS AND FRUIT OF COCOA NUT PALM. B, staminiferous flower; C, pistilliferous flower. A, section of fruit; *a*, husk, or pericarp; *b*, shell or endocarp; *c*, albumen; *d*, cavity within it; *e*, embryo; *f*, aperture of shell; *g*, rudiment of other aperture.

series, forming, therefore, a calyx and corolla; the outer whorl is often the smaller. The stamens are commonly six in number, sometimes, however, only three, and occasionally indefinite. The ovary is superior, generally divided into three cells, of which each contains a seed; the styles and stigmas of the three carpels are more or less adherent. In the ripe fruit, however, it is commonly found that the seed of only one cell has been developed; and that the other cells are therefore obliterated. In the common Cocoa-nut we have an example of this; the fruit, when covered with the husk, is evidently three-lobed; and when the husk is detached from the shell, the latter exhibits three spots upon its rounded end, of which two are hard, whilst the other is soft and easily perforated. The fibrous husk is the outer wall of the ovarium; the shell is the inner wall, with which the seed is in close contact. If the Cocoa-nut be cut through lengthways, by a section passing through the middle of the soft spot, it will be found that the small embryo is situated just beneath it, lying in the midst of the firm fleshy albumen; and we understand, therefore, that the two hard spots indicate the positions of the two embryos which have not been developed. In the Date-Palms, the staminiferous and pistilliferous flowers grow on separate trees; and the fertilisation of the latter is dependent upon the conveyance of the pollen from the former, which is usually accomplished by the agency of the wind, of insects, &c. But if unseasonable weather, or any accident, should prevent this, the Date crops entirely fail, or the fruit is degenerate and unfit for food. In order to prevent such an occurrence, the Arabs, many tribes of whom rely almost entirely on this tree for their supplies of food, have long been accustomed to gather the stamineous clusters, and to hang them over the pistilline flowers; and they even lay up stores of pollen from year to year. When they make inroads into the districts inhabited by hostile tribes, they cut down the stamen-bearing palms, as one of the most severe injuries they can inflict. It is on record that the threat of doing so, on the part of those attacked, once warded off an invasion. The Grand Signior having meditated an invasion of the city and territory of Bassora, the prince

of that country prevented it, by giving out that he would destroy all these palms on the first approach of the enemy, and by that means cut off all supplies of food from them during the siege. The facts that had been well ascertained by the experience of ages respecting the Date-Palm, were very important to Linnæus, in supporting the doctrine of the relative functions of the stamens and pistil, of which he was the first to give a correct exposition; for although this is now universally admitted to be correct, it was at first, like other novel doctrines, most vigorously opposed by many.

723. The Stems of Palms are the best of all examples of Endogenous structure. They are frequently so dense externally, as to bear the stroke of a sharp hatchet without injury. This is caused by the very close interweaving of the woody bundles that descend from the leaves, with those previously forming the exterior; for although they at first pass down through the soft centre of the stem, they direct themselves outwards near its bottom, and penetrate like roots into the exterior mass of fibres already thickly interwoven. In most of the species with long slender trailing stems, the exterior is additionally hardened by a copious deposition of silex, as in the Grasses; this is especially the case in the Rattan, which will readily strike fire with steel.

724. Palms are exclusively confined to the regions bordering on the tropics in both hemispheres. They scarcely range beyond 40° north and south of the equator; but particular species are found somewhat beyond these limits. Their chief habitation is South America, where they mostly abound in the low and humid parts of the country, though some species rise upon the sides of mountains, almost to the limits of perpetual snow. In general each species is confined within very narrow limits; it is related by Humboldt, that in travelling through the central part of South America, he found a new species at almost every fifty miles. Although nearly two-thirds of the Palms at present known are natives of South America, none have yet been found in South Africa, where the distance from the Equator is the same. Some species, however, appear to be very easily spread by the agency of Man, or by natural causes; and this, by the

kind provision of a beneficent Creator, is especially the case in regard to those which are most capable of being made useful to him. The Cocoa-nut, for example, is found in almost all the islands of the Polynesian Archipelago; even in those as yet untenanted by Man, which have been upraised by the agency of minute coral-building polypes, from the depths of the sea. This is easily accounted for, when it is considered that the Cocoa-nut may float a long time in the sea, without the seed receiving any injury, in consequence of its protection by the fibrous husk and dense shell; but when cast up by currents of the ocean on the low shores of these islands, the husk gradually separates, under the combined influence of the sun, air, and occasional moisture, and allows the seed to be acted on by those influences which will excite it to germination. The Cocoa-nut, like other species which are capable of living in a variety of conditions, has a great tendency to run into subordinate varieties; and as many as thirty of these are sometimes known to the natives of a single island, whose attention is called to them by the important benefits they derive from them, and who distinguish them by different names. The same is the case, in a less degree, with the Date-Palm, and with other species.

725. It would be impossible here to enumerate all the uses to which the various parts of these important trees, and their products, are applied by the inhabitants of the countries where they abound; since these include almost every one, for which all other tribes of the Vegetable Kingdom are employed, by those that respectively possess them. Wine, oil, wax, flour, sugar, salt, says the celebrated traveller Humboldt, are the produce of this tribe; whilst their own fabric affords the materials of the habitations, vessels, weapons, and clothing, of many nations. A few, only, of the more remarkable of these uses can here be adverted to. The exterior of the stems, of most species, affords a wood which is extremely valuable for its hardness, sometimes even taking a very high polish; in many countries, this is the only kind of timber which the inhabitants possess; and it must therefore serve all the purposes for which wood is required. Of the hardest parts, weapons are usually manufactured; and these

possess such density, as to be no unfit match for those of iron. Sections of the stem, the soft interior being removed, are converted into drums; and the stems, split lengthways, and channeled out, are employed as conduits for water. The soft interior, in most of the large-stemmed species of the Palm tribe, resembles the pith of Exogens in its freedom from woody bundles, consisting entirely of cellular tissue; and it usually contains a large quantity of starch, which renders it very nutritious. This is obtained as food from many species, but especially from what is called the Sago Palm, in which it is particularly abundant. The unexpanded buds also, at the extremity of the stems of many species, furnish a wholesome article of food; this is especially the case in a species known in the West Indies by the name of the Cabbage-Palm, from the similarity in flavour between its buds, when boiled, and ordinary Cabbage. This palm, when growing by itself in favourable situations, is one of the stateliest and most elegant of the whole race; the author has himself seen one in the island of St. Vincent, the height of which was ascertained to be above 220 feet. But when growing in thick woods, which prevent the full influence of the sun upon its bud, the stem is dwarfed; and it is then not unfrequently cut down, for the sake of the product just named. At the base of each leaf of many Palms, there is a sort of sheath composed of a fibrous network, which is probably a modification of a stipule; this is used by the Indians to form cradles, and also a sort of coarse cloth. The leaves are used entire to form thatch, fences, and fuel; the midribs furnish oars; and the fibres of the leaves, like those of the husk of the Cocoa-nut, are spun into thread, from which cords, cables, and woven fabrics of various degrees of fineness, are manufactured. The rope made from the fibres of the Cocoa-nut husk, which is known under the name of Coir-rope, is nearly equal in strength to hemp, and is considered superior to it for cables, on account of its great elasticity. The sap of the Palms, which flows in great abundance from the spathes when wounded, is a very pleasing beverage, and contains a considerable quantity of sugar; this may be separated by boiling it down; or it may be converted by fermentation into alcohol, so as to make a sort

of wine (the Palm Wine of Africa), or to afford the material for distilling spirit (the genuine Arrack of India). Many of the Palms furnish a fruit, which is wholesome and palatable, as well as of great value, from the large amount in which it is produced. The Cocoa-nut is well known to Europeans as of this character; and when picked in its young state, it is far more eatable, than when grown to the age at which it must be left, in order to bear a long voyage without injury, and at which alone, therefore, it is known in this country. Its oil, as formerly stated, has now become an important article of commerce; and from its shell many useful utensils are manufactured, by the Indian nations amongst whom it grows. The Date, however, though less known in this country, is not less important to one portion of the human race, than the Cocoa-nut to another. A considerable part of the inhabitants of Egypt, Arabia, and Persia, subsist entirely on its fruit; upon that which does not properly ripen, and upon the ground date-stones, the camels are fed. A single Date-palm will bear upwards of a hundredweight of Dates in a season, and sometimes more than twice that amount. They come into bearing at from six to ten years of age; and are fruitful for upwards of two hundred years. To all the uses already enumerated, the tree itself is applied, and many more might be mentioned; for so numerous are they, that, as Gibbon informs us, the native writers have celebrated in prose and verse not less than 360 different purposes. It is very interesting to observe that, over a large part of the district in which the Date-palm abounds, none of the Corn-grains can be raised, in consequence of the extreme dryness of the soil, and the want of moisture in the air. The sea-shores, the banks of rivers, and all parts of this region, in which there is humidity, are exceedingly fertile; but along the verge of the desert, and in the smaller Oases or islands, which are here and there met with as spots on the vast wilderness of sand, the Date-palm is the only vegetable upon which Man can subsist. The more lowly vegetables are mostly of the Cactus or Euphorbia tribe, whose juices are usually too acrid to allow of their being used as food. About two hundred species of Palms are known, of which there is not a single representative in

Britain. It has been estimated that the total number of species may probably amount to a thousand, many hundreds no doubt yet remaining to be discovered.

726. Allied to the Palms in the arborescent character of their stems, and in some degree, also, in the structure of their organs of fructification, is the small order of PANDANEÆ, or *Screw-pines*. Their chief peculiarities consist in the spiral arrangement of the leaves, from which the common name is derived; and in the peculiar mode in which the roots descend, to which attention has already been directed (§. 110). The flowers are diœcious or

FIG. 196.—PANDANUS, OR SCREW PINE. *a*, *b*, *c*, aerial roots partly serving as stems; *d*, *e*, roots not yet reaching the ground.

polygamous; the perianth is wholly wanting, and there is only a single stamen. The fruit generally consists of carpels partly adherent, and each containing a single seed. A large number of flowers are clustered, as in the Palms, on a single spadix. The best known species of this order is cultivated by the Malays and

in Japan, on account of the perfume of its staminiferous flowers, which is said to be one of the richest known. The fruit is eatable; and the various parts of the tree are used, in the countries where it abounds, for the same purposes as those to which the Palms are applied.

727. Nearly allied to the Pandaneæ in regard to its organs of fructification, though very different in aspect and habit, is the order TYPHACEÆ, the *Bullrush* tribe. These are for the most part low herbaceous plants, growing in marshy places in temperate climates. The common Bullrush, however, of this country, is not well adapted for the examination of the flowering system, as this is so extremely small as not to be readily distinguished. A better illustration is the *Bur-reed* (Sparganium) some species of which may be found in most parts of the country, growing in ditches or pools, or by the banks of rivers. One of the most common is the *Sparganium ramosum*, or Branching Bur-reed, which rises to the height of two or even three feet, and branches from the very ground. Its leaves (or bracts) are narrow, and shaped like a short straight sword-blade, sheathing the flower-stem at their lower part. At the extremities of the branches appear round balls of flowers, some of which are bright green, others bright yellow; the latter are most numerous, and are placed above the others. The former consists of pistilliferous, the latter of staminiferous flowers. Such an arrangement is almost universal, when the two sets of organs are disposed in different flowers on the same plant; the evident purpose being, that the pollen, when set free from the anthers, shall fall naturally on the pistils. If we open one of the yellow balls, we shall find that it consists of a cluster of separate flowers, each having a calyx composed of three long-stalked narrow sepals, surrounding six stamens, the anthers of which droop, in consequence of their weight being greater than the filaments can well support. In the pistilline flowers, the sepals are broader and shorter, being rolled round the pistil, and seated close upon the receptacle, without any stalk. The ovarium is one-celled, and contains but a single ovule, which hangs from its summit. It is surmounted by a stigma, which is partially cleft into two. Other plants of the

order differ from the Bur-reed in some of these particulars; in the Bull-rush, for example, the calyx is entirely wanting, being merely replaced with a quantity of delicate black hairs; and in some species there are but three stamens. The essential character of the order is derived from the incompleteness of the flowers, and especially from the structure of the ovarium, in which no trace of the number three can at any time be detected.

728. The Typhaceæ are principally confined to the northern hemisphere, and few are found in equinoctial regions. They are not of much direct importance to Man, possessing no properties which differ from those of ordinary Rushes and Sedges. Like some of these, they give an appearance of luxuriance in cold and damp situations; and they afford fodder for cattle, though poor and scanty, in situations which are otherwise barren.

729. Another group of incomplete Endogens is that of ARACEÆ, the *Arum* tribe. Of these, one species is extremely common in our hedges, and is known by the name of Wake-robin, or (to children) by that of Lords-and-Ladies. The leaves of this group seem to offer an exception to the general parallel-veining of Endogenous leaves; rather resembling the reticulated leaves of Exogens. But this is more in appearance than in reality; since it will be observed on careful examination, that the veins are *branched* (like those of the Ferns) rather than netted, and are in great measure destitute of the lateral minute branchlets uniting with each other, to which the appearance of Exogenous leaves is chiefly owing. The common species of our hedges is distinguished by usually having purple spots upon its leaves. Many Arums have large tuberous underground stems; which, although acrid and even poisonous when raw, may be rendered fit for food, by slicing, washing, and boiling. The flowering system of the Arums presents many points of interest. The first thing we notice, is the large spathe wrapping round a central column or spadix, on which the minute flowers are crowded. In the common British Arum it is green; but in others it presents a most beautiful variety and richness of colour. Sometimes it opens widely like an inverted bell, the mouth being a foot or more in diameter; in other instances, the summit is prolonged on one

side into a long slender tail. The spadix is sometimes completely covered with flowers; but in other species (as in that of Britain) it is bare of flowers at its upper part; and it then not unfrequently assumes very strange shapes and lively colours. In the Dragon-Arum of our gardens, it is a long purple horn, projecting from a large deep purple spathe; in others it hangs down from the spathe like a slender tail; and in some cases it is enlarged into a fungus-like excrescence of disagreeable appearance.

730. If we open the spathe of the common spotted Arum, we should find it to be whitish in its interior, and closely enveloping the lower part of the Spadix. On detaching the latter from it, we find at the bottom several tiers of round ovaria, which do not possess any proper style or stigma, but have a sort of puckering at their points, which serves the purpose of the latter. Each is one-celled, and contains two erect ovules. Above these are two or three rows of abortive or undeveloped ovaria, in the form of horned pear-shaped bodies. Above these, again, there is a crowd of stamens with very short filaments; and these are surmounted by another cluster of abortive ovaries. Here, we have a large cluster of pistilliferous and staminiferous flowers, in which the floral envelopes are entirely wanting, and in which, therefore, the separate flowers can scarcely be distinguished. Each ovarium, however, is the essential part of a pistilline flower; whilst every cluster of anthers is the essential part of a stamineous flower; so that

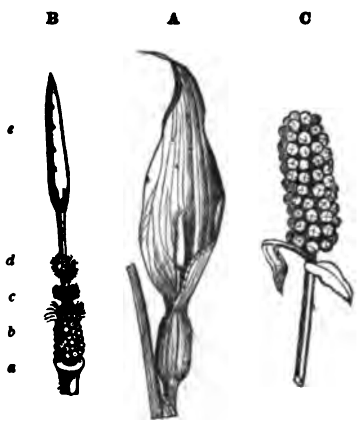

FIG. 197.—ARUM MACULATUM. A, spathe with spadix enclosed; B, spadix separated, showing *a*, ovaria; *b* and *d*, abortive ovaria; *c*, staminiferous flowers; *e*, naked part of the spadix; C, cluster of berries ripened on the spadix.

here we have the most necessary organs of fructification, reduced almost to the lowest condition in which they can exist. In a few of the tribe, however, a perianth is present, consisting of four or six pieces. The fruit of the common Arum ripens in the form of a spike of orange-coloured roundish berries, each containing but a single seed. Other species of the order differ from this in the spadix being entirely covered with flowers, in the absence of abortive ovaries, and in such other details. The peculiar character of the order is derived from the close arrangement of the flowers upon the central column or spadix, and the inclosure of the whole within a large spathe.

731. The Araceæ are very abundant in tropical countries, but become fewer in number in proportion to the distance from the equator. In cold or temperate climates they are usually herbaceous; but in tropical countries they attain a considerable size, frequently growing over large trees, to which they cling by means of aerial roots. They are for the most part acrid, and some species are extremely poisonous: one of the most remarkable effects which any of them produce, is occasioned by the Dumb Cane (as it is called), a native of the West Indies and South America, which has the power, when chewed or even bitten, of causing the tongue to swell to such a degree that it cannot be moved in the mouth; at the same time occasioning very severe pain, from which recovery does not take place for some days. The stems or rootstocks, however, possess this acridity in a diminished degree; and as it is further dissipated by heat, they become valuable articles of food. Those of the Spotted Arum are used for this purpose in the Isle of Portland; and the starchy produce obtained from them is even sent to London, under the name of Portland Sago. In the West Indies, the tubers of another species are commonly eaten under the name of Eddoe. One of the most innocent species is that known in Britain under the name of Scented Flag-rush (Acorus calamus), which is aquatic in its habits, as its common name implies. The rhizoma of this plant contains a considerable quantity of an aromatic essential oil, which imparts its fragrance to the mealy

matter through which it is diffused; hence this is consumed in large quantities by perfumers and the makers of hair-powder. It is also employed in medicine as a tonic and cordial. This order is very interesting to the Physiologist, on account of the example which it affords of the development of heat during the process of flowering (§ 419).

732. There now only remain to be considered two orders of Endogens, which bear a strong general resemblance to each other, and, indeed, are not always readily separated. One of these is that which has been spoken of as pre-eminently useful to Man,—the order GRAMINEÆ, or *Grass* tribe; the other, the CYPERACEÆ, or *Sedge* tribe, is almost as completely useless. They agree in the peculiar character of the floral envelopes, which constitute what is known as the *husk* or *chaff* of corn, the separate pieces or scales being termed *glumes*. These are regarded by the scientific botanist as metamorphosed bracts. The Sedges may be, for the most part, readily distinguished from Grasses, by their having stems which are solid and angular, instead of round and hollow; besides which, there is no hard partition at the joints. Moreover, the flowers are (with few exceptions) only protected by a solitary glume or bract. In some species all the flowers contain both sets of organs; others are monœcious, and others again are diœcious. The stamens are usually three in number, but are sometimes fewer, and occasionally more numerous. The ovarium is often surrounded by little bristles, which are perhaps the rudiments of an undeveloped perianth, as no other traces of calyx or corolla can be found; it contains one seed; and its style is usually single, dividing at the top into two or three stigmata. The fruit, when ripe, is a hard frequently three-cornered nut, indicating the original formation of the ovarium from three carpels. The seed presents a remarkable difference from that of Grasses; for the embryo is a minute roundish undivided body, lying buried within the albumen, at its lower extremity, instead of being placed on its side, as it will be presently shown to be in the Grasses (§. 735).

733. To the Sedge tribe belong many of the plants which are popularly considered as Rushes, and which are employed in the manufacture of candles, mats, and chairs; amongst the most remarkable of the British species is the *Club Rush*, which sometimes grows to the height of nine feet. This order is perhaps more widely distributed than any other, except the Grasses. Several of its members are found in marshes, ditches, and by running streams; others flourish in meadows and on heaths; others in groves and forests, others on the loose sand of the sea-shore, others on almost naked rocks, and others on the barren sides and summits of mountains. In the most northern climates, their number equals that of the Gramineæ; but as we approach the Equator, the proportion very much diminishes, both by the increase of the Grasses, and the diminution of the Cyperaceæ. Some of this tribe have a large rhizoma, which may be employed for the same purposes as that of the edible Araceæ. One of the most interesting plants belonging to the group is the *Papyrus*, famous as having afforded to the Ancients the chief of their materials for writing, from which our word *paper* is derived, although the nature of the *thing* is entirely different. The former uses of this plant, which is a native of Ethiopia and Egypt, were many. The roots were chewed for the pleasant juice they yield; and the Egyptians used to roast their stalks, and eat the soft pulpy matter they contain. The stalks afforded materials for ropes and cables; and the leaves were employed, as they are at the present time, to make the small boats, in which the inhabitants of the banks of the Nile venture upon its waters. Although the Papyrus generally prefers stagnant pools and lakes, yet it will grow in rapidly-running streams; and in such circumstances the angles of its three-cornered stem adapt it to break the force of the current. The material used for writing on is commonly said to have been prepared from the leaves of the plant; this is not the case, as it was obtained by separating the thin plates of cellular tissue, which lie just beneath the exterior of the stem; those nearest the centre being esteemed the best. These were then trimmed at their edges, so as to meet equally,

and laid side by side on a hard flat table; and other pieces, similarly cut, were laid across them at right angles. They thus formed a sheet of many pieces, which required a means of adhesion, to become one united substance when closely pressed together. This union was effected simply by sprinkling them with water; since they themselves contain a sufficient amount of gummy and saccharine matter, to adhere when this is dissolved by the water. The ancient Egyptians made sheets of a prodigious length; the celebrated traveller Belzoni had one which was 23 feet long by 1½ broad. From Egypt it was long exported in large quantities, especially to Greece and Rome; and was the only material employed for writings destined to be preserved, until the invention of parchment, which took place about 250 B. C. This for a long time, however, did not supersede papyrus, the demand for which at Rome continued for a long time after the Christian era. The supply was interrupted by the invasion of Egypt by the Saracens, in the seventh century; and as parchment was then generally substituted for it, the demand no longer existed. The latest notice of its regular manufacture brings it down to the eleventh century. The quantity made by the ancient Egyptians must have been enormous, judging by the number of rolls frequently found in the tombs, and in the mummy-cases. In the Museum of Naples, there are nearly 1800 MSS. of this description, which have been dug out of a small part of the city of Herculaneum; whence the number that must have existed in the Roman Empire at that time, may be in some degree guessed at. The paper produced from this substance, however—so far as can be judged of by the specimens which have been preserved to us, and by the attempts which have been made to revive the manufacture—was inferior to the paper we now produce from linen and cotton rags, in every respect save durability.

Order GRAMINEÆ, *or Grass Tribe.*

734. The general appearance of the ordinary GRAMINEÆ or *Grasses*, is familiar to every one; their hollow, cylindrical and jointed stems, with their long narrow leaves, distinguish them readily from all other plants. But we are not so commonly in the habit of associating, with the humble kinds with which we are familiar, the tall Sugar Canes and gigantic Bamboos of tropical climates; yet these are only Grasses on a larger scale, agreeing with our own in every essential particular, and differing mostly in size. The amount of variety in subordinate characters among the several genera and species of this large order, is very considerable; and it will be only attempted here, to give a sketch of what may be regarded as the typical structure of the organs of fructification. It will be found convenient to begin with the

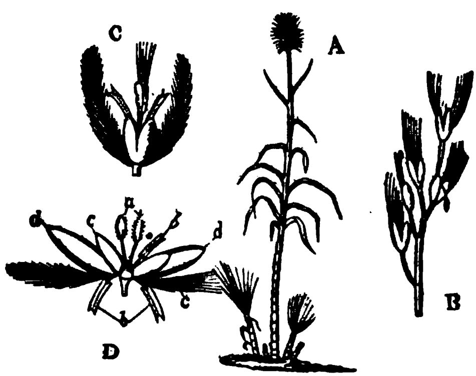

FIG. 198.—SUGAR-CANE WITH ITS FLOWERS. A, whole plant; B, cluster of flowers enclosed in glumes; C, single flower enlarged, with glumes separated; D, flower opened, showing *a*, stigmas, *b b*, stamens, *c*, scales, *d*, paleæ.

inner rather than with the outer part of the flower. In the Sugar-Cane, for example, on separating the parts of the flower, we observe the centre occupied by an ovarium, having two styles surmounted by hairy stigmas; and round this are disposed three

stamens, with large anthers supported on very slender filaments. The number of these varies in different tribes; but they are in general three; though sometimes six (as in Rice), and occasionally only one or two, are developed. In some Grasses, the two sets of organs are disposed in distinct flowers, sometimes on the same plant, and sometimes in different ones. The envelopes of these consist of several wrappings of little scales, which have received various designations. The inner pair, which are usually very small and thin, closely sheathing the ovary, are termed *Scales;*

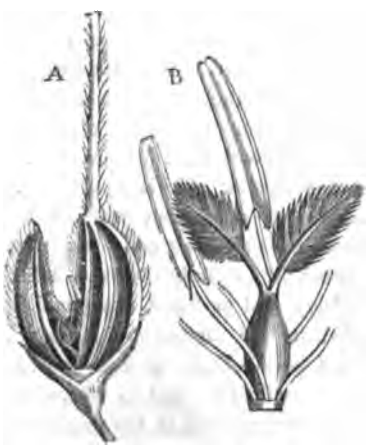

FIG. 199.—FLOWER OF RICE, ENLARGED. A, showing paleæ and awn; B, ovarium of stigmas, with two of the six stamens.

FIG. 200.—A CLUSTER OR PANICLE OF FLOWERS OF THE RICE PLANT, with its sheathing bract or glume.

externally to these, surrounding the stamens, are two others which are called *Paleæ.* These again are enclosed between another pair, which are the *glumes.* The midrib of one palea or one glume is often prolonged into a bristle-like termination,

which is called an *awn*. Where the flowers are arranged in spikelets, termed *locustæ*, each of these has one or a pair of glumes at its base by which it is more or less enclosed. Of all these parts, the interior *scales* are the only ones which bear any resemblance to the calyx or corolla of more perfect flowers; the remainder are to be considered as bracts.

735. If the ovary be cut across, nothing but a kind of pulp will be found within it; this substance then fills the young ovule, which entirely occupies the cavity of the ovarium; and its own envelopes and the walls of the ovarium grow together, in such a manner as to be scarcely distinguishable. When ripened, however, the ovary becomes hard; and its own walls and the membranes of the seed having coalesced still more closely, all trace of the originally distinct seed-vessel is lost. Such a seed, which appears destitute of an external casing, but which has really been developed within one, is properly termed a grain (see §. 504). The great mass of the seed consists of the separate albumen; and the embryo itself is very minute, and not easily discovered by an unpractised Botanist. If the grain be laid upon its flat face, so that the convex side is uppermost, a minute oval depression will be seen towards the narrowest end; and if the seed-coat be carefully removed, a little oval body will be found lying half embedded in the albumen. If this be divided perpendicularly with a sharp knife, it will be found to consist of a thickish scale, which is the single cotyledon; and upon this lies a little conical body, composed of several minute sheaths fitted one over the other, which is the plumula; whilst at the opposite extremity will be found the radicle, or rudiment of the root. When the radicle first begins to grow, the cotyledon swells a little, and attaches itself firmly, by the whole of its absorbent surface, to the albumen; and this, as it is gradually changed in the process

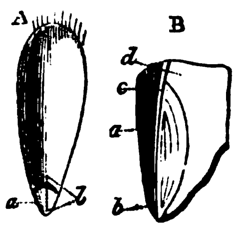

FIG. 201.—SEED OF GRASS A, external view, showing *a*, depression at the end, and *b*, position of embryo; B, section, showing the plumula *a*, the radicle *b*, and the cotyledon *c*, the whole embryo being on the outside of the albumen *d*.

of germination, is absorbed by that surface, and supplied by it to the plumula and radicle, until they have attained sufficient development to absorb and prepare nutriment for themselves, by which time the store laid up in the albumen is exhausted. This provision enables the germination of the seed to take place with much greater rapidity, than we usually find in those which have a separate albumen; for in the latter, the surface by which the young plant absorbs from it is much smaller, the cotyledon being sent upwards around the young stem.

736. In general, the true stems of Grasses are hidden, like those of several other Endogenous tribes, as well as of Ferns, beneath the earth; and the stalks which bear the organs of fructification are not to be considered in this light. In the *Bamboos* of tropical climates, however, the true stems elevate themselves into the air, sometimes to the height of 50 or 60 or even 100 feet, sending out lateral branches. The internal structure of the rhizoma of the Grasses is strictly Endogenous; as is that of the *culms* or hollow stems, if examined at the period of their first development; and their subsequent hollowness results merely from the development of the fibrous portion of their structure, which forms the exterior, faster than the cellular parenchyma increases to fill it. This form of the stem is a very beautiful illustration of the mode in which the greatest possible strength may be obtained with the least expenditure of material. (See MECHAN.

FIG. 302.—AGROSTIS CAPILLARIS. *a*, the bivalvular one-flowered glume; *b*, the same opened, showing the flower; *c*, the flower taken out to show the leaves of the calyx, and the two scales; *d*, the seed.

PHILOS. §. 83.) Some of the Grasses have, instead of a rhizoma or an upright stem, a long creeping stem, which runs near or upon the surface, sending down roots into the soil, and developing leaf and flower buds at intervals. This tendency has already been adverted to as very troublesome in the Couchgrass (*Triticum repens*); but it is of great service to Man in the grass termed the Sand-Reed (*Ammophila arenaria*) and others, which can vegetate amidst dry and drifting sand, and are hence employed to give firmness to embankments, which they pierce with an entangled web of living structure, that offers a resistance rarely overcome by the force of storms, and is renewed as fast as it is destroyed. Such grasses do not increase so much by seeds, as by the multiplication of buds; cattle will not eat them, and hence they are providentially adapted to escape that mode of destruction; but when they have been uprooted by the thoughtlessness or ignorance of Man, the most serious evils have arisen. In Scotland, for example, large tracts of once fertile country have been rendered barren, by the encroachment of sand hills, which have given them the desert-like aspect of Egyptian plains; and this encroachment has resulted from the wanton destruction of the *mat grasses*, which were pulled up by the country people for fuel, to such an extent, that an Act of Parliament was passed about an hundred years ago, rendering it punishable to do so.

737. Less need be here said of the uses of this tribe to Man, since they are more obvious than those of most others, especially to the inhabitants of temperate climates. When it is considered that all the Wheat, Barley, Oats, Rye, and other Corn-grains used as food by Man,—as also Rice, and Maize or Indian Corn, which support an even larger number than the former,—the Sugar, which is now become not only an article of luxury to him, but of necessity,—and the various grasses that form the staple food of nearly all the animals, upon which he relies for the supply of his appetite and for assistance in his labours,—it will be at once seen that no single tribe can be compared with the Gramineæ in importance to him. We have had to notice other tribes and even particular species, which are of the most

important benefit in certain situations; such are the Date and the Cocoa Nut. But these are valuable, just because the Grasses, which are otherwise universal in their distribution, are prevented, by peculiarities of climate or other causes, from flourishing in those particular spots. In all but the very coldest parts of Europe, we find some of the corn-grains affording the principal supplies of food;—barley and oats in the north, rye in latitudes a little more southern, and then wheat. In the Southern parts of Europe, rice and maize come into ordinary cultivation; and the use of these extends throughout the tropics.

738. The various provisions for the natural propagation of these important vegetables are extremely interesting. The animals which browse upon them usually prefer the foliage, leaving the flower-stalks to ripen their seed; or, if they destroy both, the plant spreads by offsets from the underground stems. Even if they be trodden down, they are not destroyed; for buds are developed from the several nodes of the stem, which thus multiply the plant. It is on exposed downs and barren places, where the heat is insufficient to ripen the seeds, and where there is no germination, that we find the tendency to multiply by buds most remarkable.

739. It may give some idea of the enormous amount of subsistence afforded by the Grasses, to state that, some years ago, when the population of Britain was much less than it is at present, it was calculated, after a laborious series of investigations, that 416 *million bushels* of corn are annually consumed in Britain, besides 100,000 bags of rice, and 200,000 tons of sugar. It has been estimated that there are upwards of a million of horses employed in Britain in different ways, each requiring as much vegetable food as would support eight men; the value of their pasturage, therefore, must be fully one-third of that from which the quantity of corn just mentioned is produced. Further, it has been stated that, not computing pork, bacon, or poultry, upwards of 150 million pounds of meat are annually consumed in London alone; and this amount should probably be multiplied by at least ten, to represent the consumption of the country in general. Again, it has been calculated that the value

of the butter and cheese, annually made in Britain, is not less than £5,000,000. These and many other animal products are almost entirely obtained from the plants of this order; which, however insignificant in appearance, have been obviously adapted, in a peculiar manner, by an All-bountiful Creator to the varied wants of his human offspring.

740. In speaking of the uses of the Grasses to Man, that of the Bamboos should not be forgotten. To the Indian Savage they afford almost all that he wants, except the food which he derives from his rice or his maize. "With their lightest shoots he makes his arrows, the fibres of the wood form bow-strings, and from the larger stems he fabricates a bow; a long and slender shoot affords him a lance-shaft, and he finds its hardened point a natural head for the weapon. With the hardened stems he builds the walls and roof of his house; its leaves afford him an impenetrable thatch; split into narrow strips it gives him the material for weaving his floor-mats, and other articles of domestic convenience; its fibre furnishes him with twine, and its leaves provide him with paper, when he becomes sensible of the utility of such a material. Would he commit himself to the waves, the stems form the hull of his boat, which by a few skins stretched over it is rendered water-tight; they also give him masts, and then slips of wood become cordage, or are woven into sails." Even in more civilised countries, such as China, India, and Japan, they are applied to a great number of useful purposes. Water-pipes are often made of them; and they are used in the construction of fences, in building houses and boats, and in the manufacture of various articles of furniture. Short sections of the stems, cut so as to include the nodal partition, are employed for a great variety of useful purposes; the small ones serve as cups; and the large ones (which are sometimes more than a foot in diameter) for tubs and boxes.

741. The table on the opposite page exhibits, in a simple form, the characters by which the foregoing orders may be distinguished from each other, and from other tribes of Endogens which have not been here noticed.

I. Flowers Complete.

A. Ovary *inferior*.
  a, Veins of leaves diverging from the midrib.
    α, Anthers 2-celled.
      Stamens 3 . . . . *Scitamineæ*
      Stamens 6 . . . . *Musaceæ*
    β, Anthers 1-celled . . . . *Marantaceæ*
  b, Veins of leaves parallel with the midrib.
    α, Flowers gynandrous . . . . *Orchideæ.*
    β Flowers not gynandrous.
      Anthers turned outwards . . *Iridaceæ*
      Anthers turned inwards.
        Stamens 6 . . . . *Amaryllideæ*
        Stamens more than 6 . . *Hydrocharaceæ*

B. *Ovary superior*.
  a, Sepals resembling petals.
    α, Flowers on a Spadix . . . . *Palmaceæ*
    β, Flowers not on a Spadix.
      Anthers turned inwards . . *Liliaceæ*
      Anthers turned outwards . . . *Colchicaceæ*
  b, Sepals green or scaly.
    α, Carpels separate . . . . *Alismaceæ*
    β, Carpels consolidated . . . . *Juncaceæ*

II. Flowers Incomplete.

A. Flowers glumaceous.
  a, Stems hollow . . . . . *Gramineæ*
  b, Stems solid . . . . . . *Cyperaceæ*

B. Flowers naked, or with a few verticillate scales.
  a, Flowers on a Spadix.
    α, Anthers on weak filaments . . . *Typhaceæ*
    β, Anthers nearly sessile . . . . *Araceæ*
  b, Flowers not on a Spadix.
    α, Ovules pendulous . . . . *Naiadeæ*
    β, Ovules erect . . . . . *Lemnaceæ*

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THE END.

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5, GREYSTOKE-PLACE, FETTER-LANE, HOLBORN.

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